PB-240 066

RADIOLOGICAL HEALTH DATA AND REPORTS. VOLUME 9, NUMBERS 10-12, OCTOBER - DECEMBER 1968

Public Health Service
Washington, D. C.

December 1968

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

BIBLIOGRAPHIC DATA SHEET

1. Report No.
RHDR 9 (10-12)

2.

PB 240 066

4. Title and Subtitle
Radiological Health Data and Reports
Volume 9, Nos 10-12

5. Report Date
Oct-Dec 1968

6.

7. Author(s)
None

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
U.S. Department of Health, Education, and Welfare
Public Health Service
Washington, D. C. 20201

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address
U.S. Environmental Protection Agency
Office of Radiation Programs
401 M St., S. W.
Washington, D. C. 20460

13. Type of Report & Period Covered
Final: Oct-Dec 1968

14.

15. Supplementary Notes

16. Abstracts

Data and interpretation of data on radiation exposure to humans and on radioactivity in milk, water, air, and other environmental media are presented.

17. Key Words and Document Analysis. 17a. Descriptors

Radiation
Radioactivity
Air
Water
Milk
Food
Human

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
US Department of Commerce
Springfield, VA. 22151

PRICES SUBJECT TO CHANGE

18. Availability Statement
Release unlimited

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

21. No. of Pages
235

22. Price PC/MF
7.50/2.25

1

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 9, Number 10, October 1968

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the National Center for Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

Department of Defense
Department of the Interior
Department of Agriculture
Department of Commerce
Department of Health, Education, and Welfare
Atomic Energy Commission

CONTENTS

Page

REPORTS

A Pilot Survey of X-radiation Emissions from Color Television Receivers in Pinellas County, Florida 525
Technical Services Branch, National Center for Radiological Health

A Summary of the Washington, D.C. Metropolitan Area Survey of Color Television Receivers 531
Technical Services Branch, National Center for Radiological Health

TECHNICAL NOTES

Summary of Gonadal and Genetically Significant Dose from X Rays in the United States, 1964 539
Phyllis Segal and *Morton L. Brown*

DATA

SECTION I. MILK AND FOOD 545

National and International Milk Surveillance 546
1. Pasteurized Milk Networks, June 1968, *PHS* 546
2. Canadian Milk Network, June 1968 549
3. Pan American Milk Sampling Program, June 1968, *PAHO* and *PHS* 550

State Milk Surveillance Activities 551
1. Colorado Milk Network, April–June 1968 552
2. Florida Milk Network, April–June 1968 553
3. Tennessee Milk Network, April–June 1968 554
4. Texas Milk Network, April–June 1968 555

2

CONTENTS—continued

Page

Food and Diet Surveillance 557

1. Radionuclides in Institutional Diet Samples, January–March 1968, *NCRH* and *NCUIH* 557

SECTION II. WATER 561

Gross Radioactivity in Surface Waters of the United States, April 1968, *FWPCA* 562

Tritium in Surface Water Network, 1967, *PHS* 564

Radioactivity in Minnesota Municipal Water Supplies, July–December 1967 566

Radioactivity in New York Surface Water, June–December 1967 568

SECTION III. AIR AND DEPOSITION 570

Radioactivity in Airborne Particulates and Precipitation 570

1. Radiation Alert Network, June 1968, *PHS* 571
2. Canadian Air and Precipitation Monitoring Program, June 1968 574
3. Mexican Air Monitoring Program, June 1968 575
4. Pan American Air Sampling Program, June 1968, *PAHO* and *PHS* 576

SECTION IV. OTHER DATA 578

Environmental Levels of Radioactivity in Mexico, January–June 1967 578

Strontium-90 in Human Bone, July–September 1967, *PHS* 602

Strontium-90 in Human Vertebrae, 1967, *HASL* 605

Environmental Levels of Radioactivity at Atomic Energy Commission Installations 610

1. National Reactor Testing Station, July–December 1967 610
2. Oak Ridge Area, July–December 1967 613

Reported Nuclear Detonations, September 1967 617

Synopses iii

Guide for Authors .... Inside back cover

RADIOLOGICAL HEALTH DATA AND REPORTS

Published under the direction of

James G. Terrill, Jr., Director and
Dr. Raymond T. Moore, Deputy Director
National Center for Radiological Health

by the Standards and Intelligence Branch
Donald L. Snow, Chief

BOARD OF EDITORIAL ADVISORS

Dr. Harold O. Wyckoff
Department of Defense

Milton W. Lammering
Department of the Interior

Dr. Ronald G. Menzel
Department of Agriculture

Reuben Pomerantz
Department of Commerce

Robert E. Simpson
Food & Drug Administration, DHEW

John A. Harris
Atomic Energy Commission

STAFF

Managing Editor
Samuel Wieder

Assistant Managing Editor
Kurt L. Feldmann

Senior Technical Editor
Marvin Rosenstein

Technical Editors
Warren A. Brill
William H. Oates, Jr.

Address correspondence to the Managing Editor, *Radiological Health Data and Reports*, National Center for Radiological Health, 12720 Twinbrook Parkway, Rockville, Md. 20852.

For subscriptions to *Radiological Health Data and Reports*, please use the order form on last page of this issue.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Environmental Control Administration • National Center for Radiological Health

3

Reports

A Pilot Survey of X-radiation Emissions from Color Television Receivers in Pinellas County, Florida

Technical Services Branch, National Center for Radiological Health

A pilot survey was conducted in Pinellas County, Florida, in November 1967 to evaluate methodology and techniques for use in determining the effectiveness of General Electric Company's modification program of color television receivers and in assessing the total radiation emission situation for television sets of all manufacturers. The instrument used was designed by the National Center for Radiological Health to facilitate rapid home surveys. To further document the source, size, shape and intensity of emissions, radiographic films were exposed on selected receivers.

The primary object of this survey was to evaluate the effectiveness of the downward beam modification program. Within the limits of this survey, the General Electric Company's downward beam modification program was found effective. The initial survey determined that 43 of the 148 sets had x-ray emissions in excess of 0.5 mR/hr; after modification, all sets emitted less than 0.5 mR/hr. A second object of the survey was to evolve and test new instruments and new methods of measurement for a future survey of television sets produced by all manufacturers.

In the spring of 1967, the General Electric Company undertook a program to modify approximately 110,000 large-screen color television receivers by replacement of high-voltage shunt regulator tubes. The object of the modification program was to correct a downward emission of x radiation emanating from the high-voltage shunt regulator tube. The Company reported that practically all of the sets had been modified by the summer of 1967.

Following notification of the problem and of the modification program by the General Electric Company, the Public Health Service (PHS) investigated the radiation emission from regulator tubes used in color television receivers (*1*, *2*). The studies described the measured x-ray distributions in direction, quality and intensity from the shunt regulator tube.

The PHS indicated to the House Subcommittee on Public Health and Welfare of the House Committee on Interstate and Foreign Commerce (*3*) and to the Senate Commerce Committee (*4*) that the effectiveness of the modification program should be verified through laboratory and field tests by the National Center for Radiological Health (NCRH). This report describes participation of the NCRH with the Pinellas County (Florida) Health Department in a pilot survey conducted in November 1967.

Survey design

The NCRH made arrangements in October 1967 with the Pinellas County Health Department to conduct a joint survey to test the methods and procedures required for radiation surveys of home color television receivers. Pinellas County, Fla. was selected as the site for the survey because of the county's special

---

[1] The film dosimetry packs contained two 14x17 inch films, one of high sensitivity for recording low radiation doses and the other of a lower sensitivity for recording higher doses.

interest in the problem and previous efforts to achieve control over the x-ray emissions from television receivers. The specific objectives of the survey were: (1) to check the results of the modification program carried out by the General Electric Company on certain large-screen color television sets in Pinellas County; (2) to evaluate methodology and techniques applicable to a more extensive evaluation of the downward beam from shunt regulator tubes; and (3) as far as possible, to develop techniques for the assessment of the total radiation emission situation for sets of all manufacturers.

The manufacturer had distributed color television sets in Pinellas County potentially capable of emitting x rays in excess of the 1960 recommendation of the National Council of Radiation Protection. The recommendation states that "the exposure rate at any readily accessible point 5 cm from the surface of any home television receiver shall not exceed 0.5 mR/hour under normal operating conditions." The Company had modified those color television sets already purchased by having local servicemen replace the high-voltage shunt regulator tubes (type 6EA4, 6EF4, or 6LC6) originally in the receivers with improved tubes (type 6EH4, 6EJ4, or 6LH6) and readjust the regulated high-voltage supply to the cathode ray tube. The service representatives were not equipped to measure x-ray emission.

Estimates of the x-radiation exposure rates from the television receivers in the home were obtained by a large-area Geiger-type survey meter scan of the exterior surfaces of the set. To further document the source, size, shape and intensity of emissions, radiographic films[1] were exposed on one or more surfaces of selected receivers having radiation emissions above 0.5 mR/hr. Later in the survey, film was used only on sets having emission rates above 2.5 mR/hr. The films were then sent to the NCRH headquarters in Rockville, Md., where they were developed and analyzed by visual and optical density measurements. A detailed description of the procedure is given in an earlier report (*5*).

The manufacturer's technical personnel who accompanied the survey teams provided technical assistance and followup, including the adjustment of operating high voltage and the replacement of receiving tubes when this was necessary to reduce x-ray emission. The shunt regulator tubes in each receiver were replaced by an improved version of the tube designated 6EH4A, 6EJ4A or 6LH6A as appropriate to each individual set. The appropriate tube replacement and/or proper high-voltage adjustment reduced the radiation to an acceptable level in all cases. This exchange program provided the NCRH with a sample of the tubes for use in laboratory tests.

Instrumentation

The instrument used in the survey was designed and constructed expressly for surveying radiation from television receivers (*6*) and received its initial field test in Pinellas County. The radiation-sensitive element of this instrument is an array of six Victoreen type 1B85 Geiger-Mueller counters. They are connected to a common high-voltage supply. Individual solid state circuits measure the current through each counter. The outputs of these counter readout circuits are connected to the input of the circuit in such a manner that the meter indicates only the reading of the counter with the highest output. This connection has the sensitive area of one counter for calibration. The large sensitive detection area provided by the six tubes allowed a surveyor to make a complete traverse of all set surfaces in 10 minutes. The instrument was easily handled in any position by one person. The location and approximate size of radiation beams could be estimated by depressing a switch which turned off all detector tubes except the end one.

Since the primary objective of the survey was to check the results of the modification program, instruments were calibrated using a downward emission from a shunt regulator tube. Using this calibration, a meter reading of 4,000 on the instrument is equivalent to 0.5 milliroentgen per hour (mR/hr).

During the initial survey operation, current leakage across the bases of the G-M survey counters, due to humidity, caused high background counting rates. The problem was solved by thoroughly drying the bases of the 1B85 detectors and encapsulating them with silicone rubber.

Survey procedures

The necessary local arrangements for visits to the set owners were made by the Pinellas County Health Department. All known modified receivers in the county were listed in alphabetical order by name of the owner and each set was assigned a code number. An introductory letter issued by the County Health Department was sent to each owner describing the purpose of the survey. Appointments were arranged in advance by telephone. When set owners could not be reached by telephone, the survey teams called in person.

Surveys of television receivers in homes were conducted by three teams. Each team consisted of a representative of the Public Health Service, Pinellas County, and the manufacturer. On entering the home, the householder was asked to turn the set on and obtain a normal picture. The manufacturer's representative observed the picture and determined whether the set operation appeared normal. The team surveyed the set on all sides, top, and bottom, for x-ray emissions. Succeeding steps depended upon the conditions found, which were classified into one of four categories as follows:

Condition 1—set operation appears normal—instrument reading less than 4,000:

(1) serviceman measured line voltage, survey of set was made, and team leader recorded meter readings;
(2) serviceman replaced shunt regulator tube and adjusted anode voltage;
(3) team leader recorded tube types and properly identified old tubes with the set;
(4) set was turned on and readjusted;
(5) a resurvey was made and meter readings noted on report forms.

Condition 2—set operation appears normal—instrument reading at or above 4,000:

(1) serviceman measured line voltage;
(2) team leader made judgment on use of film after consultation with owner;
(3) when used, film was applied by tape to the identified area or areas of maximum emission. Film was identified by set code number;
(4) when film was used, a cumulative timer was connected to record set operating time, or arrangements were made with the owner to operate the set continuously for sufficient time to deliver an estimated minimum of 10 mR to the film. Films were removed at a prearranged time by the team;
(5) serviceman measured line voltage and anode voltage, replaced tube(s) identified as source(s) of emission, reset anode voltage and readjusted picture;
(6) team leader resurveyed the set and recorded the information.

Condition 3—set operation appears abnormal—instrument reading less than 4,000:

(1) serviceman designated the probable cause of any malfunction,
(2) team leader asked the owner to observe the picture, asked whether he had noticed any difficulty, whether he regularly used the set, and whether the set had been repaired or adjusted since the modifications were completed
(3) the survey was continued as for Condition 1.

Condition 4—Set operation appears abnormal—instrument reading at or above 4,000:

(1) proceeded per (1) and (2) under Condition 3;
(2) proceeded per (1) through 6) under Condition 2
3) in the event that instrument readings above 4,000 were measured after completing the survey, the team leader advised the owner that servicing was needed and recommended distances and viewing positions to limit radiation exposure. After servicing was reported by owner as having been completed, a resurvey of the set was made.

In some instances measurements were also made with the set brightness adjusted to the darkest usable picture to indicate whether the shunt regulator tube was the primary source of radiation.

6

It took approximately 30 minutes to complete a survey of a set. The visits were arranged so that the teams were working within a small geographical area of the county at any given time. This kept travel time between surveys at a minimum. Each survey team, working full time, was able to complete approximately seven surveys per day.

Information recorded

For each set the model number and serial number were recorded. In addition to the radiation levels measured for each set, estimates of the size of the radiation field and location of the center of the radiation field on the set surfaces were entered on the survey form. Information concerning the date of modification and any servicing since modification was recorded. For each set a determination and record was made by the team leader as to whether survey instrument readings from the set were below 4,000. Where film packs were used, the film pack identification number and the exposure time were recorded.

The Public Health Service personnel participated in surveys of 143 sets and the county personnel completed surveys of five additional sets. Ten other sets could not be surveyed for the following reasons: one refusal, eight sets could not be located or had been moved from the county, and one set was returned for service and repair. The sets surveyed included four "B" model chassis and one "D" model chassis. These are models of color television sets which were not included in the Company's modification program.

Using the instrument calibration and certain assumptions (*5*), the recorded data were converted to mR/hr and are presented in tables 1 and 2. Table 1 shows the number of color television receivers by x-radiation exposure rate and operating high voltage. The line voltage was found to vary from 110 to 127 volts. The anode voltages measured ranged from 19 kV, d.c. to over 30 kV, d.c. (the shunt regulator tube voltage is about 400 volts, d.c. lower). The location of maximum x-radiation exposure rates on home color television receivers is shown in table 2.

Summary of findings

(1) There were no detected instances of either downward or frontward emitted radiation in excess of 0.5 mR/hr. Where levels of emission were detected, they appeared to be from a component source within the receiver that could be associated with the sets of all manufacturers (*6*).

(2) The location of radiation leakage on the television receivers indicated that x rays from the high-voltage rectifier tube as well as from the shunt regulator tube was a significant factor. Patterns identified by photographic film exposed on a selected number of television receivers suggest the rectifier tube as a probable primary source of lateral x-ray emission.

(3) It was observed that the operating high voltage in the majority of the sets surveyed

Table 1. Number of color television receivers by x-radiation exposure rate and operating high voltage

X-radiation exposure rate (mR/hr)	Operating high voltage (kilovolts)											Total sets
	21	22	23	24	25	26	27	28	29	30	Unknown	
< 0.040	3	6	4	16	15	3	—	—	—	—	7	54
0.040- <0.075	—	—	1	2	1	1	—	—	—	—	—	5
0.075- <0.125	—	—	—	—	—	2	—	—	—	—	—	2
0.125- <0.25	—	—	—	6	12	2	1	—	—	—	—	21
0.25 - <0.50	—	—	3	6	12	1	—	—	—	—	1	23
0.50 - <1.00	—	—	—	3	6	7	3	—	—	—	2	21
1.00 - <2.00	—	—	—	4	7	2	—	1	—	—	1	15
2.00 - <3.75	—	—	—	1	—	—	—	—	—	—	—	1
3.75 - <7.50	—	—	—	1	2	—	1	—	—	—	—	4
7.50 - <12.50	—	—	—	—	—	—	—	—	—	—	—	—
≥12.50	—	—	—	—	—	—	—	—	1	1	—	2
Total	3	6	8	39	55	18	5	1	1	1	11	148
Percent exceeding 0.5 mR/hr	—	—	—	23.1	27.3	50.0	80.0	100.0	100.0	100.0	27.3	29.1

Table 2. Location of maximum x-radiation exposure rates on home color television receivers

X-radiation exposure rates (mR/hr)	Number of sets by location of the highest exposure rate measurement *						Total sets
	Bottom	Left	Top	Front	Right	Back	
0.040- <0.075	—	2	—	—	—	3	5
0.075- <0.125	—	1	—	1	—	—	2
0.125- <0.25	—	17	—	1	—	3	21
0.25 - <0.50	—	18	1	—	—	4	23
0.50 - <1.00	—	18	—	—	—	3	21
1.00 - <2.00	—	11	—	—	—	4	15
2.00 - <3.75	—	1	—	—	—	—	1
3.75 - <7.50	—	4	—	—	—	—	4
7.50 - <12.5	—	—	—	—	—	—	—
≥12.5	—	2	—	—	—	—	2
Total	—	74	1	2	—	17	94

* A number of sets had the same exposure rate on more than one side. The priority for placement in the table is the following: front, left, top, back, bottom, and right. "Left" is the set surface on the viewer's left.

was above the value recommended by the manufacturer at the line voltage encountered. Since an extensive modification program had been performed in Pinellas County and instructions had been given to the repairmen on the proper voltage setting, it was not expected that these high operating voltages would be found. Therefore, high operating voltages may be a major cause of the high emission rates from the high-voltage rectifier tube. The effect on the x-ray emission of varying the high voltage of the rectifier is illustrated in table 3. It was also noted that in many cases x-radiation emission was reduced when the high voltage was adjusted to the level recommended by the manufacturer. Laboratory tests conducted by the NCRH have shown that excessive operating voltage can result in x-radiation emissions from tube components (*1*, *2*).

Table 3. X-ray exposure rates from a rectifier tube at various voltages

Kilovoltage (kV)	X-ray exposure rates (mR/hr)
27	10
26	5
25	3
24	1
23	0.35

(4) A resurvey of the sets showed all sets to be within the recommended level after a service adjustment was made to each set in Pinellas County that had an x-ray emission above the recommended level of 0.5 mR/hr. This adjustment included exchange of the shunt regulator tube, exchange of the high-voltage rectifier tube, and adjustment of the operating high voltage. Appropriate tube replacement and proper high-voltage adjustment reduced x radiation to an acceptable level in all cases.

(5) Incidental to the survey, a 6EA4 tube was found in a "B" model chassis. This is a different model of the General Electric television receiver from those included in the GE modification program. A radiation level in excess of 12.5 mR/hr was observed at the side of the set to the viewer's left. An exchange of the shunt regulator tube and a voltage adjustment corrected this radiation problem.

Conclusions

(1) In the sets surveyed, the problem of downward directed x-ray leakage had been corrected by replacement of the original high-voltage shunt regulator tubes (type 6EA4, 6EF4, 6LC6) with replacement tubes (6EH4, 6EJ4, or 6LH6) and in the later stages of the modification program, the "A" version of these tubes. The review of the survey reports of 148 sets showed that within the limits of the survey instrument used, only two sets had a measurable radiation level at the bottom of the set. These levels were below the meter reading of 4,000.

(2) The high-voltage rectifier appeared to be the major source of radiation. In many cases the emission was due in part to a high-voltage setting greater than that recommended by the manufacturer.

8

Acknowledgments

Arrangements for the survey were made by George McCall, public health physicist, Pinellas County Health Department, and Mr. D. J. Nelson, Jr., assistant to the director for laboratories, National Center for Radiological Health. Mr. Nelson served as the overall director of the project. Members of Mr. McCall's staff, Mr. Clyde Stagner and Mr. Dale Rees, served as the survey team leaders. Mrs. Russell Hobbs, Pinellas County Health Department, arranged the appointments for the surveys in the homes. Mr. Roger Schneider, Electronic Products Radiation Laboratory, was the project coordinator for the NCRH in Pinellas County, and Mr. Donald Smith, Technical Services Branch, NCRH, was the project officer.

The necessary local arrangements for visits to the set owners were made by Dr. John T. Obenschain, director, Pinellas County Health Department, and Mr. George McCall, public health physicist, Pinellas County Health Department.

The instrument used in the survey was designed and constructed by Mr. Richard K. Stoms and Mr. Edward Kuerze, National Center for Radiological Health, Cincinnati, Ohio.

REFERENCES

(*1*) STEWART, H. F., N. F. MODINE, E. G. MURPHY and J. W. ROLOFSON. X-ray patterns and intensities from high voltage shunt regulator tubes for color television receivers. Radiol Health Data Rep 8:675–686 (December 1967).

(*2*) RECHEN, H. J. L., T. R. LEE, R. H. SCHNEIDER and O. G. BRISCOE. Measurements of x-ray exposure from a home color television receiver. Radiol Health Data Rep 8:687–697 (December 1967).

(*3*) U.S. CONGRESS. Subcommittee on Public Health and Welfare, the House Interstate and Foreign Commerce Committee, relative to H.R. 10790, Hon. John Jarman, Chairman, August 14, 1967.

(*4*) U.S. CONGRESS. Senate Committee on Commerce, relative to S. 2067, Hon. E. L. Bartlett, August 29, 1967.

(*5*) TECHNICAL SERVICES BRANCH, NATIONAL CENTER FOR RADIOLOGICAL HEALTH. A survey of X-radiation from color television sets in the Washington, D.C. metropolitan area. TSB Report No. 3 (March 12, 1968).

(*6*) STOMS, R. K. and E. KUERZE. Instrument for measurement of x-ray emission from television sets. Technical papers, Conference on Detection and Measurement of X-radiation from Color Television Receivers, Washington, D.C., March 1968.

A Summary of the Washington, D.C. Metropolitan Area Survey of Color Television Receivers

Technical Services Branch, National Center for Radiological Health

A survey was conducted by the National Center for Radiological Health (NCRH) during December 1967 and January 1968 with the cooperation of the Electronic Industries Association and individual manufacturers to obtain x-ray emission data from color television receivers owned by Public Health Service employees in the Washington, D.C. area. Radiation measurements, using a survey instrument developed by the NCRH, were made on 1,124 color television sets of various makes and models. Of these sets, 66 emitted x rays at exposure rates were at or in excess of the recommended level of 0.5 mR/hr. The x-ray emissions were reduced to acceptable levels through service adjustments, such as replacement of shunt regulator or rectifier tubes and reduction of the operating high voltage. The survey results are considered to be valid only for the sample of sets examined in the Washington, D.C. area.

The Public Health Service announced in May 1967 that the General Electric Company had sold certain large-screen color television sets, produced between June 1966 and February 1967, which had the potential of emitting higher than desirable levels of x rays (*1*). The source of the problem was a defective high-voltage shunt regulator tube. The Company undertook to correct the approximately 110,000 affected sets through a nationwide modification program based upon a replacement of the faulty tubes.

During Congressional hearings in the summer and fall of 1967, the Public Health Service indicated that the effectiveness of the Company's modification program would be verified through laboratory and field tests (*2*). The x-ray emission characteristics of shunt regulator tubes and other high-voltage components were investigated in two National Center for Radiological Health (NCRH) laboratories (*3–5*). A joint pilot survey was also undertaken by the Center with the Pinellas County (Florida) Health Department to check the results of the General Electric Company modification program in that County (*6, 7*). As a result of these investigations, radiation emissions observed from sources other than the shunt regulator tube indicated a potential industry-wide problem.

To obtain additional information, an x-ray survey was developed for a sample of color television sets owned by Public Health Service employees in the Washington, D.C. metropolitan area. The purpose of the survey was to obtain x-ray emission data for television receivers of all the manufacturers included in the sample. The survey, conducted by the National Center for Radiological Health during December 1967 and January 1968, had the active cooperation of the Electronic Industries Association and individual manufacturers.

The following is a summary of information contained in the report, "A Survey of X-radiation from Color Television Sets in the Washington, D.C. Metropolitan Area," by the Technical Services Branch, dated March 12, 1968. A full description of the methodology and measurement techniques employed and an evaluation of the data is presented in the complete report.

The survey

The objectives of the survey were: (1) to obtain x-ray emission data on a variety of makes and models of color television sets operating in the Washington area, (2) to test procedures for, and to determine the feasibility and usefulness of more representative and ex-

10

tensive surveys of color television receivers, and (3) to provide information on possible sources of x radiation which could be used by manufacturers or service organizations to prevent or correct excessive x-radiation emissions. The basis for determining whether x-ray levels were excessive was the 1959 National Council on Radiation Protection and Measurements (NCRP) recommendation ". . . that the exposure rate at any readily accessible point 5 cm. from the surface of any home television receiver shall not exceed 0.5 mR per hour under normal operating conditions" (*8*).

Public Health Service employees in the Washington, D.C. area were asked to make available their color receivers for radiation measurements. A total of 1,124 sets were surveyed. These comprised a variety of brand names and models from 20 domestic and five foreign manufacturers. Representatives from these manufacturers and from two retail distributors provided technical support for surveys involving their particular sets.

Visits to homes to obtain x-ray emission measurements and other essential data were begun on December 16, 1967. Survey teams, composed of Public Health Service and industry representatives, visited an average of seven homes per day. As many as nine teams were in the field at any one time during the survey.

The Public Health Service representatives made the radiation measurements, recorded data, and interviewed the set owner. The industry personnel assisted in identifying the color receivers and components and in measuring household line voltages and receiver operating high voltages. Where necessary, the industry representatives also made corrections so that the sets conformed to the NCRP recommendation.

X-ray emission measurements were made using a survey instrument developed by the NCRH Electronic Products Radiation Laboratory (*9, 10*). This Geiger-Mueller-type instrument was designed and constructed expressly for the purpose of rapidly and accurately obtaining in-home measurements of color television x-ray emissions.

For the purpose of the Washington survey, the survey instrument was calibrated with an x-ray beam from a 6EF4 shunt regulator tube operated at 25 kV, d.c. between the anode and cathode. This beam uniformly irradiated the detector at exposure rates between 0 and 12.5 mR/hr. The exposure rates for the calibration x-ray beam were determined by a Victoreen model 440 RF Survey Meter; this secondary system had been calibrated by means of a General Electric Maximar 100 self-rectified therapy x-ray machine and a Victoreen type 326, 10 roentgen ionization chamber having National Bureau of Standards calibration for lightly filtered x rays. The energy response of the 440 RF was essentially independent for the x-ray spectrum under consideration. The beam had a first half-value layer of 0.5 mm of aluminum. A level of 0.04 mR/hr was the minimum exposure rate that could be detected by the survey instrument.

Each set was operated in a condition as normally viewed and radiation measurements were made at 2 inches from all outer surfaces. The exposure rates determined in this manner were compared with the NCRP recommendation.

If a set was emitting in excess of 0.5 mR/hr, an attempt was generally made to use radiographic film (*11*) as a supplementary survey technique. The film measurements provided additional information on the exposure rate, size, shape, and possible source of the x-ray emission. The film technique was also used in some cases to study situations where emission levels were less than 0.5 mR/hr as determined with the survey instrument.

Limited information on viewing habits was obtained through discussion with household members while the survey measurements were being made. In order to avoid extension of the time required for home visits, the use of a questionnaire or the formal interview technique was not employed.

Results

Radiation emission was detectable from a variety of makes and models of 1,124 color television receivers surveyed (see table 1). Table 2 gives the distribution of color television receivers by the highest x-radiation exposure rates as measured by the NCRH survey instrument under home operating conditions. X-radiation emissions were not detected from 856

Table 1. X-radiation emission from color television receivers

Receiver name	Sets surveyed	Sets with x radiation at or above 0.04 mR/hr [a]	Sets with x radiation at or above 0.5 mR/hr [b]
RCA	360	78	20
Zenith	162	58	19
Sylvania	100	7	0
Motorola	75	32	4
GE	72	5	0
Sears	71	18	1
Magnavox	69	23	[illegible]
Philco	45	3	0
Airline	33	13	1
Admiral	30	5	0
Westinghouse	19	1	0
Heath	18	1	0
Dumont	16	0	0
Penncrest	15	3	1
Setchell Carlson	13	13	8
Packard Bell	7	3	0
Muntz	6	1	0
Curtis Mathes	4	0	0
Delmonico	2	2	1
Symphonic	2	2	1
Bradford	2	0	0
Clairtone	1	0	0
AMC	1	0	0
Panasonic	1	0	0
Total	1,124	268	66

[a] The minimum detectable level of the instrument used was 0.04 mR/hr.

[b] 0.5 mR/hr is the maximum exposure rate at any readily accessible point 5 cm from the surface of any home television receiver as recommended by NCRP.

receivers. Exposure rates at or above the 0.04 mR/hr detectable level were recorded for 268 receivers. Of these, 66 sets had x-radiation levels at or above 0.5 mR/hr, 40 indicated levels at or above 1.0 mR/hr and 2 sets exceeded 12.5 mR/hr (the full scale reading of the survey instrument).

For the 268 sets at or above 0.04 mR/hr, x-radiation emissions were observed on six sides of 10 receivers, on five sides of 18 receivers, on four sides of 22 receivers, on three sides of 32 receivers, on two sides of 57 receivers, and on one side of 129 receivers. The highest x-radiation levels for individual sets were measured at the left side for 68 sets, at the back for 74, and at the front for 54 sets. Over 20 percent of the sets with levels greater than 0.04 mR/hr had the highest x-radiation emission from the front.

For the 66 sets with readings at or above 0.5 mR/hr, x-radiation emissions were detected on six sides of 7 receivers, on five sides of 8 receivers, on four sides of 9 receivers, on three sides of 12 receivers, on two sides of 16 receivers, and on one side of 14 receivers.

Table 3 shows the location of the highest x-radiation levels measured on the sets above 0.04 mR/hr. For the 66 sets with emissions equal to or exceeding 0.5 mR/hr, the locations of the highest levels measured were as follows: bottom—11 sets; left (of viewer)—20 sets; top—sets 2; front—sets 12; right (of viewer) —set 1; and back—20 sets.

Table 2. Distribution of color TV receivers by the x-radiation exposure rate

Receiver name[a]	X-radiation exposure rate, mR/hr										
	0.040 to <0.075	0.075 to <0.125	0.125 to <0.25	0.25 to <0.50	0.50 to <1.00	1.00 to <2.00	2.00 to <3.75	3.75 to <7.50	7.50 to <12.50	12.50 and over	Total
Admiral	2	1	0	2	0	0	0	0	0	0	5
Airline	5	1	3	3	1	0	0	0	0	0	13
AMC	0	0	0	0	0	0	0	0	0	0	0
Bradford	0	0	0	0	0	0	0	0	0	0	0
Clairtone	0	0	0	0	0	0	0	0	0	0	0
Curtis Mathes	0	0	0	0	0	0	0	0	0	0	0
Delmonico	1	0	0	0	0	1	0	0	0	0	2
Dumont	0	0	0	0	0	0	0	0	0	0	0
General Electric	1	0	4	0	0	0	0	0	0	0	5
Heath	1	0	0	0	0	0	0	0	0	0	1
Magnavox	1	1	8	3	6	0	1	1	1	1	23
Motorola	7	1	13	7	3	0	1	0	0	0	32
Muntz	0	1	0	0	0	0	0	0	0	0	1
Packard Bell	1	1	1	0	0	0	0	0	0	0	3
Panasonic	1	0	0	0	0	0	0	0	0	0	1
Penncrest	1	0	1	0	0	1	0	0	0	0	3
Philco	0	0	1	2	0	0	0	0	0	0	3
RCA	14	14	18	12	6	9	1	2	2	0	78
Sears	2	6	6	3	1	0	0	0	0	0	18
Setchell Carlson	0	1	3	1	1	1	1	2	2	1	13
Sylvania	4	1	1	1	0	0	0	0	0	0	7
Symphonic	0	0	0	1	1	0	0	0	0	0	2
Warwick	0	0	0	0	0	0	0	0	0	0	0
Westinghouse	0	0	0	0	0	0	0	0	0	0	0
Zenith	11	10	9	9	7	11	1	0	0	0	58
Total	52	38	68	44	26	23	5	5	5	2	268

[a] The manufacturers included in the survey were: Admiral, Clairtone Electric Corporation, Curtis Mathes, Delmonico Japan, Emerson-Dumont, General Electric, Hayakawa, Heath Company, Hoffman Products, Hoffman Electronics, Magnavox, Matshushita, Motorola, Packard Bell, Philco Ford, RCA, Sylvania, Setchell Carlson, Symphonic Electric Corporation, Toshiba, TV Corporation of America, Warwick Electronics, Wells Gardner, Westinghouse, and Zenith.

Table 3. Location of maximum x-radiation exposure rates on home color television receivers

X-radiation exposure rates (mR/hr)	Number of sets by location of the highest exposure rate measurement [a]						
	Bottom	Left	Top	Front	Right	Back	Total
0.040— <0.075	8	7	12	14	0	11	52
0.075— <0.125	6	4	9	11	0	8	38
0.125— <0.25	2	23	14	9	0	20	68
0.25 — <0.50	2	14	4	8	1	15	44
0.50 — <1.00	6	7	2	3	1	7	26
1.00 — <2.00	3	6	0	5	0	9	23
2.00 — <3.75	0	2	0	1	0	2	5
3.75 — <7.50	0	2	0	2	0	1	5
7.50 — <12.50	1	2	0	1	0	1	5
≥12.50	1	1	0	0	0	0	2
Total	29	68	41	54	2	74	268

[a] A number of sets had the same exposure rate on more than one side. The priority for placement in the table is the following: front, left, top, back, bottom, and right. "Left" is the set surface on the viewer's left.

In the survey, 70 film packs were exposed on 55 receivers, 45 of which were found with x-radiation emissions at or above 0.5 mR/hr by the survey instrument. Exposure rates measured by the radiographic film technique ranged from 0.12 to 369 mR/hr as shown in table 4.

Comparison of film pack and survey instrument measurements of x-radiation exposure rates are also shown in table 4. Valid comparisons could be made with survey instrument measurements of exposure rate for 58 of 70 films. The film gave higher values than the instrument in 48 comparisons and lower values in 10 cases.

Data on line voltage and operating high voltage were obtained because of the importance of these parameters in the production of x radiation (*5*). The line voltage measurements ranged from 107 to 129 volts. The line voltage observed most often was 120 volts. The operating high voltage of a receiver can vary with the line voltage depending on the degree of regulation provided by the circuit design. The maximum variation in line voltage can produce a 20 percent change in the operating high voltage of a receiver.

Table 5 shows the operating high voltage measurements on 808 receivers and the x-radiation emissions from these sets by high-voltage intervals of 1 kV over the observed range of 18 kV to 34 kV. Some sets operating well below the observed average high-voltage level emitted excessive x radiation. However, as one would expect, there is a general increase in the proportion of sets exceeding the 0.5 mR/hr x-radiation exposure rate as operating voltages increase.

High-voltage measurements were made on 226 of the 268 sets found to be emitting x radiation at or above 0.04 mR/hr. The average observed high voltage for the 181 receivers having a shunt regulator tube and producing x radiation at or above 0.04 mR/hr was 25.8 kV; the average rated high voltage for these receivers was 24.4 kV. Eighty-two of the 181 receivers exceeded 26.5 kV. For the 45 receivers not having a shunt regulator tube and producing measurable x radiation, 27 had a high-voltage reading above 27 kV which was the average value observed for such receivers.

Table 6 gives the distribution of the highest x-radiation exposure rate measured by the year of purchase. Detectable x radiation was observed regardless of the age of the sets. The survey did not provide detailed information on the amount of servicing, including replacement of components. A service adjustment within the 2-month period prior to the survey was reported for 24 of the 66 sets with exposure rates above 0.5 mR/hr.

The probable sources of x radiation were determined from a review of the instrument measurements and the patterns formed on film. In the 55 sets studied with film, the shunt regulator tube was identified as the probable primary source in 30 of the receivers, the picture tube in nine, a combination of the shunt regulator and picture tube in six, and the rectifier tube in eight other receivers. In two sets, no specific source could be identified.

Each receiver with x-radiation emission above 0.5 mR/hr was serviced by the manufacturer's representative and resurveyed to in-

Table 4. X-radiation emission levels from color TV receivers by location, probable source and operating kilovoltage based on survey instrumentation and radiographic film measurements

Receiver case number [a]	Receiver operating voltage (kV)	Probable source of x-radiation	Location film on receiver	Time of film exposure (hr)	X-radiation exposure rates [b] (mR/hr)	
					Film	Instrument
1a	—	Picture [c]	Left	61.40	0.12	0.10
1b	—	Picture	Right	61.40	.13	.11
1c	—	Picture	Top	61.40	.15	.11
2	27.0	Rectifier	Bottom	30.50	.14	1.10
3a	—	—	Back	[d](29.00)	.15	.14
3b	—	—	Back	(29.00)	.22	.14
4	27.0	Rectifier	Back	(78.00)	.17	.19
5	29.0	Shunt or rectifier	Left	28.40	.17	.62
6	24.0	Picture	Top	(60.00)	.20	.28
7	28.5	Picture	Back	49.50	.22	.60
8	—	Picture	Top	55.50	.33	.10
9	25.5	Rectifier	Left	64.50	.36	.21
10	23.8	Picture	Back	43.20	.43	.83
11	27.0	Rectifier	Back	23.00	.43	.10
12	26.5	Rectifier	Left	30.50	.44	.19
13	24.5	Rectifier	Back	(43.00)	.52	.19
14a	25.0	Shunt	Left	(27.50)	.80	.50
14b	25.0	Shunt	Back	(8.00)	3.65	3.25
15	31.0	Shunt	Back	24.80	.90	1.10
16	26.0	Shunt	Bottom	(63.50)	.92	.88
17a	30.5	Shunt and picture	Top	61.30	1.20	2.25
17b	30.5	Shunt and picture	Left	61.30	3.17	2.25
17c	30.5	Shunt and picture	Back	61.30	12.80	7.50
18	29.0	Shunt	Left	27.50	1.34	.65
19	30.5	Picture	Left	(10.00)	1.40	2.25
20	26.8	Shunt	Left	(35.00)	1.50	.20
21a	25.0	Shunt	Back	(49.00)	1.60	1.50
21b	25.0	Shunt	Left	(49.00)	2.38	.30
22	25.0	Shunt	Front	85.00	1.76	.63
23	25.5	Rectifier	Left	(65.50)	1.84	1.00
24a	30.0	Picture	Top	5.08	1.92	1.25
24b	30.0	Shunt and picture	Back	5.08	94.50	> 12.50
24c	30.0	Shunt and picture	Back	5.08	181.00	> 12.50
25	27.0	Shunt	Back	(133.00)	2.03	1.40
26	27.0	Shunt	Back	(22.30)	2.06	1.50
27	34.0	Picture	Front	(5.25)	2.54	5.00
28	25.0	Shunt	Left	(64.00)	2.50	1.10
29	33.5	Shunt	Back	5.97	3.10	2.50
30	25.1	Shunt	Left	(12.50)	3.50	1.10
31a	26.5	Shunt and picture	Back	(13.50)	3.63	.88
31b	26.5	Shunt and picture	Left	(13.50)	4.23	1.12
32	24.0	Shunt	Back	51.60	4.09	1.62
33	24.2	Shunt	Back	(17.00)	4.60	.75
34	26.5	Shunt	Back	22.50	5.80	1.00
35	26.0	Shunt	Back	8.10	6.30	1.10
36	26.2	Shunt	Back	5.50	7.61	2.50
37	25.5	Shunt	Left	(4.00)	7.61	2.60
38	26.0	Shunt	Bottom	24.00	9.81	.81
39	25.5	Shunt	Left	(8.50)	10.60	3.75
40	24.1	Shunt	Back	(27.60)	11.40	1.10
41	31.0	Shunt and picture	Left	(21.00)	24.40	11.20
42	27.0	Shunt	Left	(6.33)	29.50	3.75
43	28.5	Shunt	Left	11.00	47.40	10.00
44	23.5	Shunt	Back	13.90	51.00	1.25
45	26.2	Shunt	Bottom	9.58	89.20	8.80
46	23.0	Shunt	Left	0.19	97.10	.55
47	28.6	Shunt	Bottom	(1.85)	100.00	12.50
48	26.0	Shunt	Bottom	(0.88)	369.00	> 12.50
49a	29.0	Picture	Left	Not recorded	—	.40
49b	29.0	Picture	Top	Not recorded	—	.70
50a	31.0	Shunt and picture	Back	Not recorded	—	1.25
50b	31.0	Shunt and picture	Left	Not recorded	—	1.50
51a	27.0	Picture	Back	Insufficient	—	.50
51b	27.0	Picture	Top	Insufficient	—	.51
51c	27.0	Picture	Right	Insufficient	—	.53
51d	27.0	Picture	Left	Insufficient	—	.53
52	24.5	Improperly located film		Insufficient	—	.63
53	27.0	Rectifier	Left	Not recorded	—	.67
54	—	Picture	Front	Insufficient	—	1.10
55	27.5	Shunt	Left	Insufficient	—	4.20

[a] Subscripts indicate where more than one film was used.

[b] For film, the x-ray measurements are based upon the optical density at the point (4 mm diameter) of highest film density. For the survey instrument, the x-ray measurements are the average x-ray intensity over a rectangle approximately 7.0 cm by 1.8 cm. If all other factors are equal, this might account for differences between film and instrument measurement results.

[c] Picture refers to picture tube.

[d] Exposure time estimated from record kept by set owner or by surveyor are shown in parentheses. Generally an in-line timer was used to record film exposure time.

14

Table 5. Number of color TV receivers by x-radiation exposure rate and opera:ing high voltage

X-radiation exposure rate (mR/hr)	Operating high voltage (kV)																	
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Total
<0.040	47	14	18	27	46	73	90	121	83	39	16	6	1	1	0			582
0.040—<0.075	0	0	1	0	2	4	6	6	10	6	5	0	0	0	0			40
0.075—<0.125	0	0	0	1	2	1	3	3	5	10	5	0	1	1	0			32
0.125—<0.25	0	0	0	2	7	7	7	7	8	7	5	5	0	0	0			55
0.25 —<0.50	0	0	0	2	3	0	3	7	3	6	6	4	2	0	0			36
0.50 —<1.00	0	0	0	1	0	3	4	4	3	4	4	1	0	1	1			26
1.00 —<2.00	0	0	0	0	0	1	3	5	4	2	0	2	1	3	0			21
2.00 —<3.75	0	0	0	0	0	0	0	2	1	0	0	0	1	0	0	1		5
3.75 —<7.50	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	1	4
7.50 —<12.50	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	1	5
≥12.50	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	2
Total	47	14	19	33	60	89	116	156	119	76	42	18	8	7	1	1	2	[a] 808
Percent exceeding 0.5 mR/hr	0		0	3.0	0	4.5	6.0	7.7	8.4	10.5	11.9	16.7	50.0	71.4	100.0	100.0	100.0	

[a] Operating high voltage measurements were not made on 316 receivers. Three of these receivers had radiation emissions above 0.5 mR/hr.

Table 6. Highest x-radiation exposure rate for color TV receivers distributed by year of purchase

X-radiation exposure rate (mR/hr)	Not recorded	1955–1962	1963	1964	1965	1966	1967	1968	Total
<0.040	31	34	16	45	103	240	385	2	856
0.040—<0.075		2		3	7	22	18		52
0.075—<0.125			2		7	14	15		38
0.125—<0.25	2	2	2	2	15	20	25		68
0.25—<0.50			1	2	14	14	13		44
0.50—<1.00	2		1	2	2	11	8		26
1.00—<2.00				3	7	7	6		23
2.00—<3.75						3	2		5
3.75—<7.50					1	1	3		5
7.50—<12.50					1	4			5
≥12.50				1		1			2
Total	35	38	22	58	157	337	475	2	1,124

sure that the x-radiation level was below 0.5 mR/hr.

The servicing adjustments included 29 tube replacements for 27 of the 66 sets at or above 0.5 mR/hr. Two rectifier tubes type 3A3A were replaced. Twenty-seven shunt regulator tubes of type 6BK4, 6BK4A, or 6BK4B were replaced. For 36 of the 66 sets above 0.5 mR/hr, high-voltage adjustments alone reduced radiation to 0.5 mR/hr or lower as measured by the survey instrument. Three receivers did not have a service adjustment recorded on the survey data collection form.

The Washington area survey provided some data on viewing habits (table 7) of 2,311 individuals in 741 households: 743 household members viewed television from less than 8 feet. Three hundred and eighty persons stated they viewed color sets in excess of 30 hours per week. Approximately 20 percent of the individuals under 15 years of age view color television more than 30 hours per week. Information given by the person interviewed in the home indicated 328 of 547 viewers under age 15 view television at less than 8 feet and 48 at distances under 4 feet.

Conclusions

1. Some x-radiation emission was observed in a variety of makes and models of the 1,124 receivers surveyed in the Washington metropolitan area.

2. One of the most important findings of the survey was that 856 of the 1,124 receivers surveyed emitted no measurable levels of x radiation. The survey results demonstrate that the

Table 7. Household members by age, normal viewing distance and hours per week viewing time

	Number of persons at viewing distance						
	Total	Under 4 ft.	4 to 7 ft.	8 to 11 ft.	12 to 15 ft.	16+ ft.	Not indicated
All ages	2,311	84	659	969	484	71	44
Viewing hr/wk:							
15 and under	1,061	49	290	442	225	39	16
16-30	845	24	239	376	179	19	8
31+	380	11	127	148	78	13	3
Not indicated	25	0	3	3	2	0	17
Under 15 years old	547	48	280	150	39	6	24
Viewing hr/wk:							
15 and under	198	22	100	53	10	5	8
16-30	219	18	104	64	25	1	7
31+	120	8	74	33	4	0	1
Not indicated	10	0	2	0	0	0	8
15-44 years old	1,049	23	232	497	255	30	12
Viewing hr/wk:							
15 and under	536	16	123	242	134	14	7
16-30	360	5	78	189	79	8	1
31+	149	2	30	65	42	8	2
Not indicated	4	0	1	1	0	0	2
45 years old and over	715	13	147	322	190	35	8
Viewing hr/wk:							
15 and under	327	11	67	147	81	20	1
16-30	266	1	57	123	75	10	0
31+	111	1	23	50	32	5	0
Not indicated	11	0	0	2	2	0	7

industry has produced color television sets that can be operated well within the National Council on Radiation Protection and Measurements' recommendation and in most instances with x-radiation emission levels approaching normal background radiation in homes.

3. The primary sources of x-ray emissions are (1) the high-voltage shunt regulator tube, (2) the high-voltage rectifier tube, and (3) the picture tube.

4. The operating high voltage for television receivers demonstrably affects production and emission of x radiation from components.

5. It is possible to reduce x-radiation emissions both through service adjustments, including replacement of shunt regulator or high-voltage rectifier tubes, and reduction of the operating high voltage.

6. The survey technique did not provide data to support a valid association of observed x-radiation conditions with individual brand name or manufacturer on a nationwide basis.

REFERENCES

(*1*) U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, PUBLIC HEALTH SERVICE. Statement by James G. Terrill, Jr., Director, National Center for Radiological Health, on May 18, 1967, concerning x radiation from certain General Electric color television receivers.

(*2*) U.S. CONGRESS. Subcommittee on Commerce and Finance, the House Interstate and Foreign Commerce Committee, relative to H.J. Res. 280, Hon. John E. Moss, Chairman, July 31, 1967.

U.S. CONGRESS. Hearings before the Subcommittee on Public Health and Welfare, the House Interstate and Foreign Commerce Committee, relative to H.R. 10790, Hon. John Jarman, Chairman, August 14, 1967.

U.S. CONGRESS. Hearings before the Senate Committee on Commerce, relative to S. 2067, Hon. E. L. Bartlett, Chairman, August 29, 1967.

(*3*) MURPHY, H. STEWART, S. COPPOLA, and N. MODINE. X-ray Emission from Shunt Regulator Tubes for Color Television Receivers, MORP 67-1. National Center for Radiological Health, 12720 Twinbrook Parkway, Rockville, Md. 20852 (June 1967).

(*4*) STEWART, H., N. MODINE, E. MURPHY, and J. ROLOFSON. X-ray patterns and intensities from high voltage shunt regulator tubes for color television receivers. Radiol Health Data Rep 8:675-686 (December 1967).

(*5*) RECHEN, H. J. L., T. R. LEE, R. H. SCHNEIDER, and O. BRISCOE. Measurements of x-ray exposure from a home color television receiver. Radiol Health Data Rep 8:687-697 (December 1967).

(6) U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, PUBLIC HEALTH SERVICE, NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Press release of December 6, 1967, concerning the need for a program to evaluate the potential health hazards of radiation from color television sets.

(7) U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, PUBLIC HEALTH SERVICE, NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Press release dated December 17, 1967, concerning a survey of x-ray emissions of color television sets in the Washington, D.C. area.

(8) NATIONAL COMMITTEE ON RADIATION PROTECTION AND MEASUREMENTS. National Committee on Radiation Protection and Measurements (Recommendations for color TV receivers with x-radiation emission). Radiology 173:122 (1960).

(9) STOMS, R. K., and E. KUERZE. Instrument for Measurement of X-ray Emission from Television Sets, TSB Report No. 1. National Center for Radiological Health, Technical Services Branch, 12720 Twinbrook Parkway, Rockville, Md. 20852 (January 1968).

(10) RECHEN, H. J. L., R. H. SCHNEIDER, and R. K. STOMS. Calibration and Energy Dependence of the EPRL X-ray Survey Meter. Technical Papers—Conference on Detection and Measurement of X-radiation from Color Television Receivers, U.S. Department of Health, Education, and Welfare and the Electronic Industries Association (March 28–29, 1968), pp. 175–184.

(11) STEWART, H. F., N. F. MODINE, and J. W. ROLOFSON. Low Energy Calibration of Film Used in Measuring X-Rays from Color Television Receivers. Technical Papers, Conference on Detection and Measurement of X-Radiation from Color Television Receivers, March 28–29, 1968. PHS, National Center for Radiological Health, 12720 Twinbrook Parkway, Rockville, Md. 20852, pp. 185–212.

Technical Notes

Summary of Gonadal and Genetically Significant Dose from X Rays in the United States, 1964

Phyllis Segal and *Morton L. Brown*[1]

The 1964 X-ray Exposure Study conducted by the U.S. Public Health Service was undertaken to obtain information on the x-ray experience of the U.S. population during that year. The study was designed in five sequential stages:

1. a household interview survey of a representative sample of the U.S. population to obtain x-ray visit data;
2. a mail followup to the x-ray facilities where reported visits took place, to obtain technical data;
3. the merging and processing of the above sets of data to produce estimates of x-ray visits and examinations by the U.S. population;
4. the development of dosimetric models for estimating gonadal dose from the exposure data generated by the X-ray Exposure Study; and
5. the estimation of gonadal doses and the genetically significant dose for the U.S. population based on the dosimetric models and the exposure data.

Estimates of the number and distribution of x-ray visits and examinations, and estimates of exposure were published in an earlier report, "Population Exposure to X-rays, U.S. 1964" (*1*). A forthcoming publication, "Population Dose from X-rays, U.S. 1964," will present the dose models developed for the study as well as estimates of gonadal and genetic dose for the U.S. population. The following is a summary of selected data from the latter publication.

Table 1 shows the mean gonadal dose (in millirads) from radiographic procedures by body area, age, and sex. Mean gonadal doses from examinations over all body areas were significantly lower for children than for adults. Other data collected in this study suggest this is due in part to lower mean doses for abdominal examinations of children and in part from the relatively higher concentration of examinations of the skull and extremities in the pediatric age group.

Table 1. Mean gonadal doses (in millirads) from radiographic procedures by body area, age, and sex United States, 1964

Body area	All ages [a]	Under 15	15–29	30–44	45 and over [a]
Male:					
All body areas	239	35	262	340	255
Head and neck	3	<1	(b)	(b)	17
Thorax	8	2	24	2	4
Abdomen	1,071	222	1,808	1.340	837
Extremities	57	9	79	11	159
Female:					
All body areas	70	16	77	106	101
Head and neck	3	(b)	(b)	9	(b)
Thorax	7	12	4	10	6
Abdomen	351	138	370	352	422
Extremities	<1	1	<1	<1	(b)

[a] Category includes females under 50 years of age and males under 65.
[b] Figure does not meet standards of reliability or precision due to small sample size.

Testicular doses resulting from examinations of the abdomen reflected the impact of beam sizes larger than the minimum size needed to expose the film. The size of the useful beam is an important determinant of the amount of x-ray exposure received by the patient during examinations. Although strict collimation of the x-ray beam to the size of the film is an effective control of excess radiation, the data in figure 1 show that beam size was frequently in excess of film size, thus producing the relatively large gonadal doses shown for examinations of the abdomen of males.

Due to the design of the study, it was possible to simulate estimates of gonadal dose which would result if beam sizes had been restricted to effective beam sizes (i.e., to the size of the receptor film) (*2*). These estimates showed

---

[1] Mrs. Segal is public health analyst and Mr. Brown is deputy chief, Population Exposure Studies, Population Studies Program, National Center for Radiological Health, Rockville, Md. 20852.

18

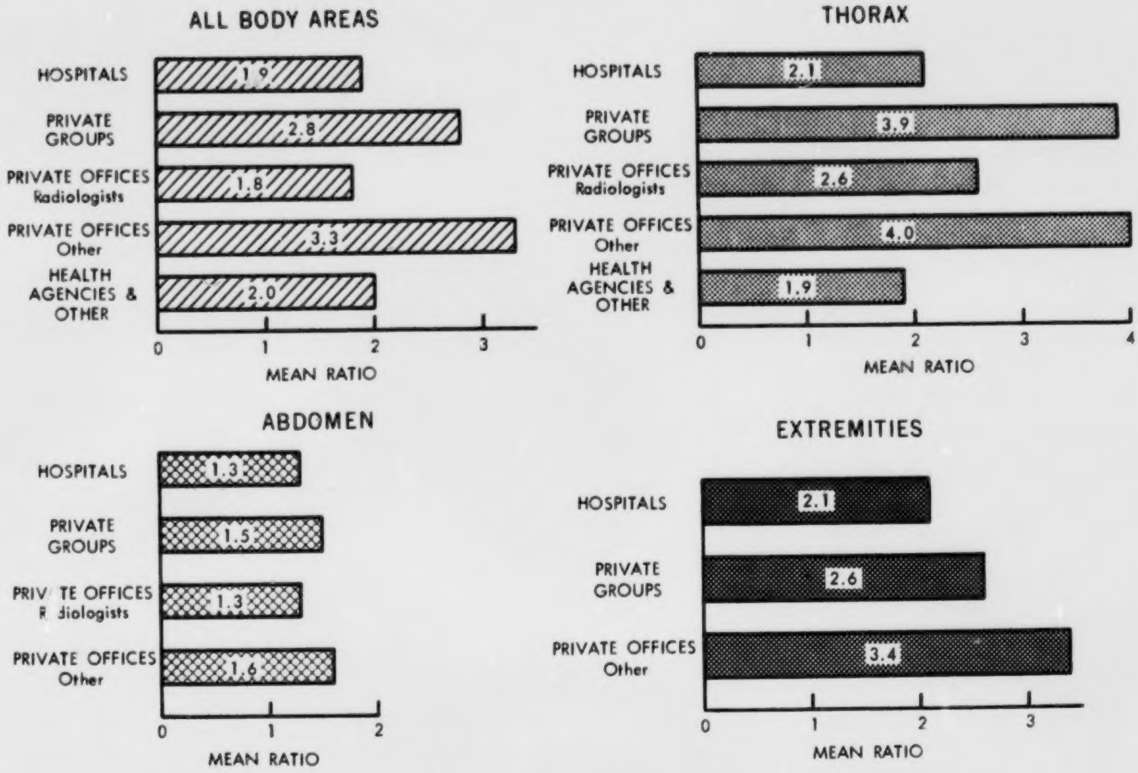

Figure 1. Estimated mean ratio of beam area to film area for radiographic films for selected body areas by type of facility, United States, 1964

a marked reduction of testicular doses. Comparable estimates of ovarian doses reflected more modest reductions due to the fact that the ovaries are located close to areas of diagnostic interest, and hence may not be excludable from the useful beam for certain examinations.

As was reported in "Population Exposure to X-rays, U.S. 1964," abdominal examinations performed in hospitals, private group practices, and by radiologists in private offices involved approximately one-half the mean exposure per film compared to those performed in the private offices of other practitioners. Table 2 presents estimates of mean gonadal doses per film by sex, body area and type of facility for radiographic examinations. While doses for thoracic films varied little among the types of facilities, the data suggest that those done in private offices of radiologists may be somewhat lower in mean gonadal dose than those done elsewhere. Ovarian doses from abdominal films varied little by type of facility. However, for males, the data indicate that testicular dose levels are higher in private offices of nonradiologists than in other facilities. Mean gonadal doses for films of the head and neck and of the extremities are also presented, although the sample size for these groups precludes comparison by facility type.

Estimated mean gonadal doses for selected types of roentgenologic examinations are shown in table 3. Gonadal doses from radiographic examinations ranged from less than 1 millirad to over 2 rads. Examinations of the abdomen and pelvis were found to yield the highest mean gonadal doses, while examinations of the head and neck and extremities yielded low gonadal doses, as might be expected.

It may be seen that mean gonadal doses for fluoroscopic examinations are low, by comparison with the comparable doses for radiographic films taken in conjunction with fluoro-

Table 2. Mean gonadal dose (in millirads) per film by sex, body area and type of facility for all radiographic examinations, United States, 1964

Sex and body area	All facilities	Hospital	Private office radiologists	Private office and other private group	Mobile unit health agencies and others
Males:					
Head and neck [a]	<1	1	<1	<1	0
Thorax [b]	6	8	4	6	<1
Abdomen [c]	273	258	281	343	7
Extremities [d]	23	35	<1	2	<1
Females:					
Head and neck [a]	1	1	<1	<1	<1
Thorax [b]	5	4	1	3	8
Abdomen [c]	100	103	71	98	0
Extremities [d]	<1	<1	<1	<1	<1

[a] Skull, cervical spine.

[b] Photofluorographic, radiographic, shoulder, thoracic spine.

[c] Cholecystography or cholangiogram, lumbar spine, upper gastrointestinal, barium enema, abdomen, KUB, flat plate, intravenous or retrograde pyelogram, pelvis or lumbo-pelvic area, hip.

[d] Upper extremities, lower extremities.

Table 3. Mean gonadal dose per examination (in millirads) by selected type of examination, United States, 1964

Type of examination	Total	Testicular	Ovarian	Fetal
Skull	2	<1	4	7
Cervical spine	5	8	2	3
Chest:				
Radiographic	6	5	8	6
Photofluorographic	4	<1	8	8
Fluoroscopic	28	1	71	([a])
Thoracic spine	139	184	9	9
Shoulder	<1	<1	<1	<1
Upper gastrointestinal series:				
Radiographic	222	130	360	343
Fluoroscopic	85	7	198	198
Barium enema:				
Radiographic	1,042	1,535	439	417
Fluoroscopic	203	50	366	397
Cholecystography or cholangiogram	88	2	193	206
Intravenous or retrograde pyelogram	1,436	2,091	407	451
Abdomen, KUB, flat plate	263	354	289	291
Lumbar spine-lumbo-sacral	1,759	2,547	420	239
Pelvis or lumbo-pelvic	604	717	41	82
Hip	917	1,064	309	366
Upper extremities	1	2	<1	([a])
Lower extremities	69	96	<1	<1
All other:				
Radiographic	69	52	92	251
Fluoroscopic	229	229	0	0

[a] Figure does not meet standards of reliability or precision due to small sample size.

scopic examinations of the gastrointestinal tract. The differential is particularly marked for testicular doses. This finding suggests that one of the major factors responsible for the low estimated fluoroscopic dose is the complete exclusion of the testes from the direct beam and partial exclusion of the ovaries, due to the small field sizes used in fluoroscopy.

In the past, fluoroscopy was known to produce high dose levels to the patient, but the data from the 1964 x-ray exposure study indicate that this may no longer be the case. This suggests that improvements in the design of fluoroscopic equipment, and the less frequent use of fluoroscopy by non-radiologists have resulted in lower dose levels from fluoroscopic examinations. The close collimation used in fluoroscopy with resulting low gonadal doses is further indication that fluoroscopy is no longer as significant a source of overexposure as in the past.

Photofluorography results in low gonadal doses since it should not involve direct beam irradiation of the gonads.

The *genetically significant dose* to a population is defined as the gonadal dose which, if received by every member of the population, would result in the same total genetic effect to the population as the doses which are, in fact, received by individuals within the population (3). The following formula was used in order to determine the genetically significant dose to the U.S. population in 1964:

$$\mathrm{GSD} = \frac{\sum_i D_i \hat{N}_i P_i}{\sum_i N_i P_i}$$

where,

D_i = the mean gonadal dose for a specified type of examination for a patient in age-sex class (i),

$\hat{N}_i$ = the number of persons in age-sex class (i) who had the specified type of examination during a year,

P_i = the expected number of future children to an individual in age-sex class (i), and

N_i = the number of persons in age-sex class (i) in the total population.

Based on the data for the U.S. population for 1964, the genetically significant dose was estimated to be 55 millirads per person, per year.

This value is compared with estimates from other studies in table 4. One obvious difference contributing to the level of genetically significant dose is the examination rate found in each study. Table 4, therefore, also shows the genetically significant dose per examination for each study, obtained by dividing the total genetically significant dose by the annual number of examinations per capita. This rate represents normalization of genetically significant dose for examination rates, while retaining the effects of dose levels and population parameters upon the genetically significant dose. Using this index, the estimate for the United States is found to be similar to values for several other countries in which examination rates are lower than those for the United States.

Other factors which should be considered in analyzing international comparisons are the level of fecundity in each country, the differences in time period covered by each study, the differences in medical practices and the differences in methodology used in the various studies, particularly with regard to dosimetry.

Approximately 96 percent of the genetically significant dose to the U.S. population resulted from radiography, 4 percent from fluoroscopy, and less than 1 percent from photofluorography.

Figure 2 shows the percent contribution to genetically significant dose by sex and age class. It may be seen that the largest single contributing group was males aged 15 to 29.

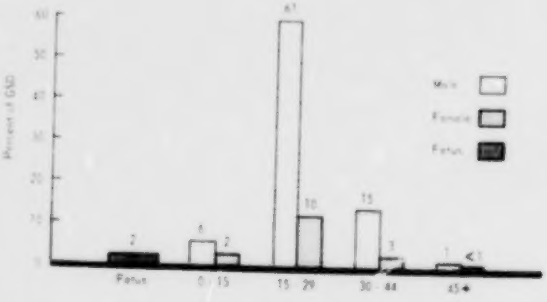

Figure 2. Estimated percent distribution of genetically significant dose from diagnostic medical roentegenology by age and sex, United States, 1964

Table 4. Comparison of annual genetically significant dose from diagnostic radiology

Locale	Investigator and date of study	GSD c	Estimated annual per capita examination rate	GSD per examination
United States	Gitlin, *et al.* (1964)	55	0.53	103
	Laughlin & Pullman (1955–1956)	d 50	.27	186
	Brown, *et al.* (1956–1957)	40	1.11	36
	Cooley & Beentijes (1960–1962)	18	.05	36
Richland, Wash.	Norwood, *et al.* (1953–1956)	45	.58	78
New York City	Heller (1962)	45	.73	62
France	Not available	58	.15	387
Sweden	Larsson (1955)	38	.29	130
Japan	Miyakawa, *et al.* (1960)	39	.41	95
Denmark	Hammer-Jacobsen (1956)	22	.24	92
Rome	Not available	43	.50	87
Great Britain	Adrian Committee (1957–1958)	14	.28	50
Leiden (Netherlands)	Nooteboom-Beekman (1959)	7	.35	20

[a] Adopted from a report by Pasternack & Heller (4) except for the 1964 United States value by Gitlin, *et al.* (1)
[b] Excluding examinations in TB centers, (including photofluorographic) and dental.
[c] Genetically Significant Dose.
[d] Their low range estimate.

The contribution to genetic dose by examination type is not proportional to the frequency of these examinations. A high percentage of the genetically significant dose is contributed by relatively few procedures. Although examinations of the thorax accounted for over 50 percent of the examinations reported in the X-ray Exposure Study, these examinations contributed only 4 percent to the genetic dose. Abdominal and pelvic examinations amounted to 25 percent of those reported in the study, yet the genetic dose from these examinations accounts for 90 percent of the total (figures 3 and 4).

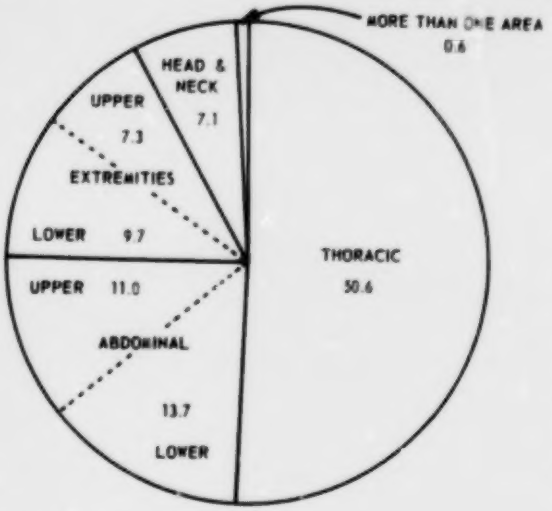

Figure 3. Estimated percent distribution of radiographic examinations by body area, United States, 1964

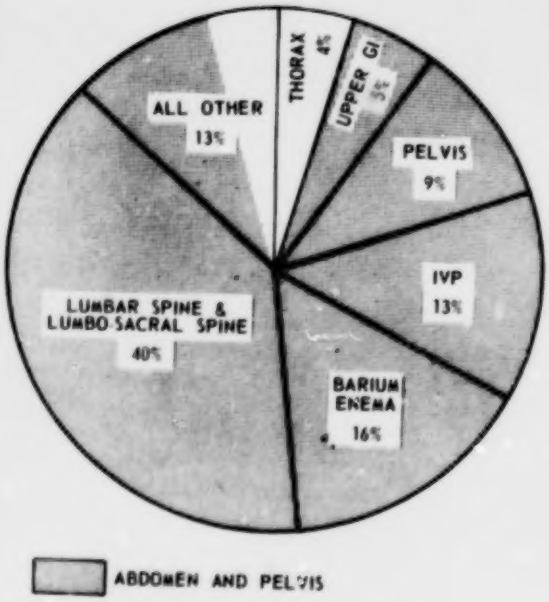

Figure 4. Estimated percent distribution of genetically significant dose by type of medical roentgenologic examination, United States, 1964

As described above, hypothetical gonadal doses calculated under the assumption that all examinations in the study had been conducted with beam sizes no larger than the film size resulted in a marked reduction of testicular doses. If this schedule of gonadal doses is used to calculate an estimated genetically significant dose, a reduction from 55 to 19 millirads per person per year, is observed. This reduction reflects only the impact of improved collimation, with no other changes in radiographic technique or in examination rates. This two-thirds reduction in genetic dose confirms the thesis that adequate collimation is the single most important factor in reducing excess population dose from diagnostic medical examinations.

REFERENCES

(1) GITLIN, J. N. and P. S. LAWRENCE. Population Exposure to X-rays, U.S., 1964. PHS Publication 1519, U.S. Public Health Service (1966).

(2) PENFIL, R. L., M. L. BROWN and A. W. HILBERG. The importance of Beam Collimation in Reduction of Patient Dose from Diagnostic Roentgenology. Presentation at American Medical Association, Section on Radiology, Atlantic City, N.J., June 1967.

(3) Report of The United Nations Scientific Committee on the Effects of Atomic Radiation; General Assembly Official Records: Thirteenth Session, Suppl 17(A/3838), New York (1958).

(4) PASTERNACK, B. S and M. B. HELLER. Genetically significant dose to the population of New York City, from diagnostic medical radiology. Radiology 90:217–228 (February 1968).

Data

SECTION I. MILK AND FOOD

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Federal and State agencies are involved in efforts to monitor continuously the dietary intake of radionuclides. The most direct measure of radionuclide intake would be obtained through radioanalysis of the total diet. Difficulties in obtaining specific dietary data impede this approach. An alternate method entails the use of indicator foods to arrive at an estimate of the total dietary radionuclide intake.

Fresh milk is one such indicator food. It is consumed by a large segment of the U.S. population and contains most of the biologically significant radionuclides which appear in the diet. It also is one of the major sources of dietary intake for the short-lived radionuclides. For these reasons, fresh milk is the single food item most often used in estimating the intake of selected radionuclides by the general population and/or specific population groups. In the absence of specific dietary information, it is possible to approximate the total daily dietary intake of selected radionuclides as being equivalent to the intake represented by the consumption of 1 liter of fresh milk.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG's) for controlling normal peacetime nuclear operations, assuming continuous exposure from intake by the population at large (*1–3*). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; they do provide an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission on Radiological Protection (*5, 6*).

Data from selected national, international, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

REFERENCES

(*1*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).

(*2*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action for strontium-89, strontium-90, and cesium-137, Report No. 7. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1965).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 5. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (July 1964).

(*5*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 2. Pergamon Press, New York, N.Y. (1959).

(*6*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 6. Pergamon Press, New York, N.Y. (1964).

National and International Milk Surveillance

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various national and international organizations routinely monitor radionuclide levels in milk.

In addition to those programs reported below, *Radiological Health Data and Reports* coverage includes:

Program	Period reported	Last presented
Radiostrontium in milk, HASL	January–December 1967	August 1968

---

1. Pasteurized Milk Network
June 1968

National Center for Radiological Health and
National Center for Urban and
Industrial Health, PHS

The Public Health Service's Pasteurized Milk Network (PMN) is designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling from major milk production and consumption areas. The present network of 63 stations (figure 1) provides data on milk in every State, Washington, D.C., the Canal Zone, and Puerto Rico. The most recent description of the sampling and

Table 1. Analytical errors associated with determinations of radionuclide concentrations in a milk sample

Nuclide	Concentration (pCi/liter)	Error [a] (pCi/liter)	Concentration (pCi/liter)	Error [a] (percent of concentration)
Strontium-89	<50	5	≥50	10
Strontium-90	<20	2	≥20	10
Iodine-131	<100	10	≥100	10
Cesium-137	<100	10	≥100	10
Barium-140	<100	10	≥100	10

[a] Two standard deviations.

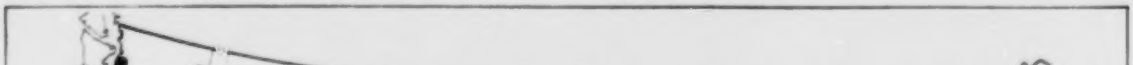
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
MAINE
N.H.
MASS.
CONN.
HONOLULU
HAWAII
PALMER
ALASKA
PR & V.I.
SAN JUAN
CRISTOBAL
PANAMA CANAL ZONE

Figure 1. Pasteurized Milk Network sampling stations

Table 2. Average concentrations of radionuclides in pasteurized milk for June 1968 and the 12-month period, July 1967 through June 1968[a]

Sample location		Radionuclide concentrations (pCi/liter)									
		Strontium-89		Strontium-90		Iodine-131		Cesium-137		Barium-140	
		July 1967–June 1968	June 1968	July 1967–June 1968	June 1968	July 1967–June 1968	June 1968	July 1967–June 1968	June 1968	July 1967–June 1968	June 1968
Ala:	Montgomery	0	0	9	9	0	0	14	19	0	0
Alaska:	Palmer	NA	NA	5	0	0	0	15	11	1	0
Ariz:	Phoenix	0	0	1	0	0	0	2	1	0	0
Ark:	Little Rock	1	0	21	27	0	0	19	24	0	0
Calif:	Sacramento	0	0	3	2	0	0	6	8	1	0
	San Francisco	1	0	2	0	0	0	4	4	1	0
C.Z:	Cristobal	0	0	2	0	0	0	10	6	0	0
Colo:	Denver	1	0	4	3	0	0	6	1	0	0
Conn:	Hartford	NA	NA	9	11	0	0	13	10	0	0
Del:	Wilmington	NA	NA	11	16	0	0	13	17	0	0
D.C:	Washington	0	0	10	12	0	0	9	17	0	0
Fla:	Tampa	0	0	8	9	0	0	68	65	0	0
Ga:	Atlanta	0	0	14	14	0	0	21	21	0	0
Hawaii:	Honolulu	0	0	3	5	1	0	5	6	0	0
Idaho:	Idaho Falls	1	0	6	8	0	0	8	8	0	0
Ill:	Chicago	0	0	9	9	0	0	10	8	0	0
Ind:	Indianapolis	NA	NA	7	9	0	0	7	3	0	0
Iowa:	Des Moines	0	0	7	10	0	0	7	8	0	0
Kans:	Wichita	1	0	9	10	0	0	5	9	0	0
Ky:	Louisville	0	0	12	14	0	0	6	16	0	0
La:	New Orleans	0	0	22	22	0	0	24	25	0	0
Maine:	Portland	NA	NA	10	14	0	0	30	31	0	0
Md:	Baltimore	0	0	10	14	0	0	5	18	0	0
Mass:	Boston	0	0	12	18	0	0	25	38	0	0
Mich:	Detroit	NA	NA	8	10	0	0	12	16	0	0
	Grand Rapids	NA	NA	10	16	0	0	14	19	0	0
Minn:	Minneapolis	1	7	11	11	0	0	12	21	0	0
Miss:	Jackson	0	0	17	20	0	0	14	19	0	0
Mo:	Kansas City	1	0	8	10	0	0	4	3	1	0
	St. Louis	0	0	9	9	0	0	7	8	0	0
Mont:	Helena	1	0	5	0	0	0	7	4	1	0
Nebr:	Omaha	1	0	8	10	0	0	5	4	0	0
Nev:	Las Vegas	0	0	2	0	0	0	4	6	0	0
N.H:	Manchester	NA	NA	13	19	0	0	34	47	0	0
N.J:	Trenton	NA	NA	10	15	0	0	10	17	0	0
N. Mex:	Albuquerque	0	0	2	4	0	0	3	6	0	0
N. Y:	Buffalo	NA	NA	8	12	0	0	11	10	0	0
	New York City	NA	NA	11	19	0	0	13	22	0	0
	Syracuse[b]	NA	NA	7	12	0	0	9	17	0	0
N. C:	Charlotte	0	0	16	18	1	0	12	12	0	0
N. Dak:	Minot	2	7	11	13	0	0	12	20	0	0
Ohio:	Cincinnati	NA	NA	9	12	0	0	7	16	0	0
	Cleveland	NA	NA	9	13	0	0	9	15	0	0
Okla:	Oklahoma City	0	0	10	15	0	0	4	11	0	0
Ore:	Portland	1	0	7	10	0	0	15	20	1	3
Pa:	Philadelphia	NA	NA	9	16	0	0	8	19	0	0
	Pittsburgh	NA	NA	12	19	0	0	14	19	0	0
P. R:	San Juan	0	0	5	6	0	0	11	14	0	0
R. I:	Providence	NA	NA	11	15	0	0	19	25	0	0
S. C:	Charleston	0	0	15	18	0	0	28	27	0	0
S. Dak:	Rapid City	1	0	10	14	0	0	10	20	0	0
Tenn:	Chattanooga	0	0	14	16	0	0	13	17	0	0
	Memphis	0	0	12	16	0	0	5	8	0	0
Tex:	Austin	0	0	4	4	0	0	3	1	0	0
	Dallas	0	0	7	15	0	0	6	16	0	0
Utah:	Salt Lake City	1	0	5	5	0	0	12	10	0	0
Va:	Norfolk	0	0	11	11	0	0	10	12	0	0
Vt:	Burlington	NA	NA	11	17	0	0	11	16	0	0
Wash:	Seattle	1	0	9	10	0	0	24	26	1	0
	Spokane	1	0	7	6	0	0	13	9	0	0
W. Va:	Charleston	0	0	12	28	0	0	4	17	0	0
Wis:	Milwaukee	NA	NA	8	8	0	0	11	15	0	0
Wyo:	Laramie	0	0	4	6	0	0	6	0	0	0
Network monthly average		0	0	9	11	0	0	12	15	0	0

[a] See text for averaging procedure.
[b] 12-month average represents only 9-months data.
NA, no analysis.

25

analytical procedures employed by the PMN appeared in the January 1968 issue of *Radiological Health Data and Reports* (*1*). Reference should also be made to the February 1968 issue (*2*), in which several changes in the interpretation and reporting of data were introduced.

Table 1 shows the approximate analytical errors (including counting error) associated with determinations of radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. Table 2 contains averages for June 1968 and 12-month averages for the period July 1967 through June 1968. The 12-month averages facilitate evaluations of population exposure with respect to the guidance provided by the Federal Radiation Council, which suggests average total daily intakes "averaged over periods of the order of a year," as an appropriate criterion (*3*). The average radionuclide concentrations are based on results obtained from samples collected weekly. Whenever weekly concentrations were less than or equal to the appropriate minimum detectable levels, zero was used for averaging purposes (*2*). At very low radionuclide concentrations this often results in averages lower than the minimum detectable concentration for a single sample, but any positive value reflects at least one weekly sample which was above the minimum detectable level. The minimum detectable concentration is defined as the measured concentration equal to the two-standard deviation analytical error. Accordingly, the minimum detectable concentrations in units of pCi/liter are: strontium-89, 5; strontium-90, 2; iodine-131, cesium-137, and barium-140, 10.

The average strontium-90 concentrations in pasteurized milk from selected cities are presented in figure 2.

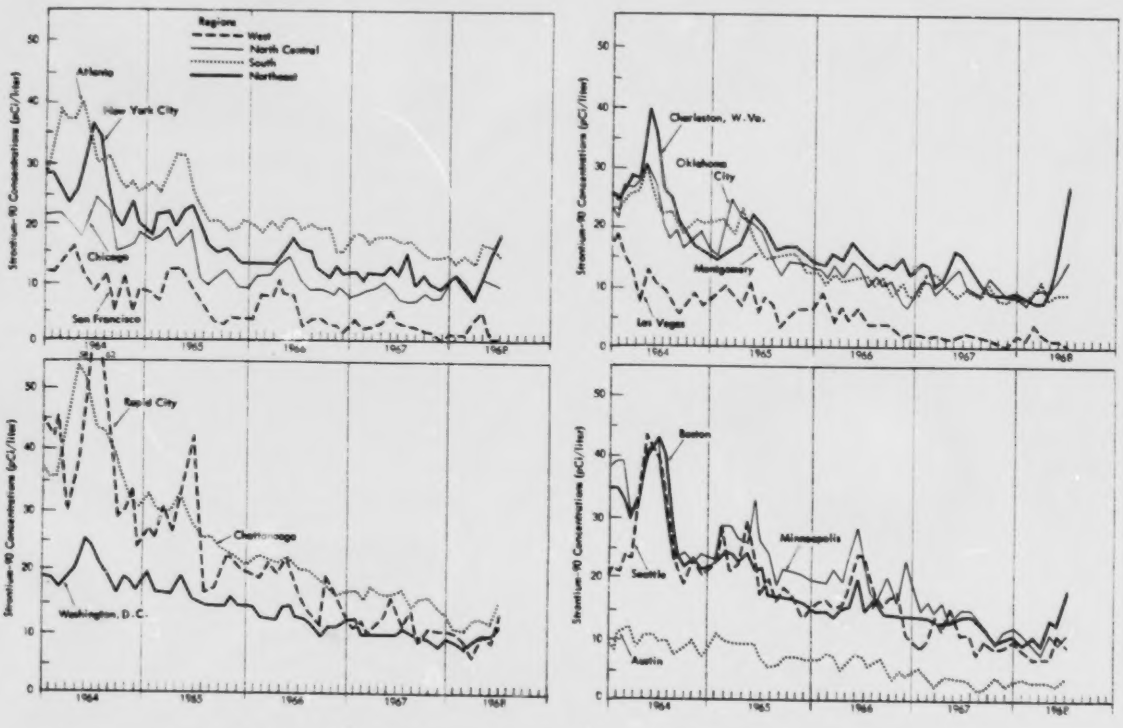

Figure 2. Strontium-90 concentrations in pasteurized milk, 1964-June 1968

2. Canadian Milk Network[1]
June 1968

Radiation Protection Division
Department of National Health and Welfare

Since November 1955, the Radiation Protection Division of the Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine–131, and monthly composites are analyzed for strontium–90, cesium–137, and stable calcium and potassium. The analytical procedures were outlined in the April 1968 issue of *Radiological Health Data and Reports* (*4*).

The June 1968 monthly average strontium–90, cesium–137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 5. Iodine–131 and strontium–89 concentrations were below minimum detectable levels.

Table 5. Stable elements and radionuclides in Canadian whole milk, June 1968

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.06	1.3	10	23
Edmonton	1.09	1.5	8	23
Ft. William	1.11	1.5	17	32
Fredericton	1.06	1.4	17	23
Halifax	1.11	1.4	12	27
Montreal	1.09	1.5	10	19
Ottawa	1.15	1.6	9	18
Quebec	1.09	1.4	16	29
Regina	1.09	1.4	7	18
St. John's, Nfld	1.11	1.4	21	44
Saskatoon	1.11	1.4	8	17
Sault Ste. Marie	1.11	1.6	18	40
Toronto	1.15	1.6	6	17
Vancouver	1.15	1.5	17	56
Windsor	1.15	1.5	6	14
Winnipeg	1.15	1.4	7	18
Average	1.11	1.5	12	26

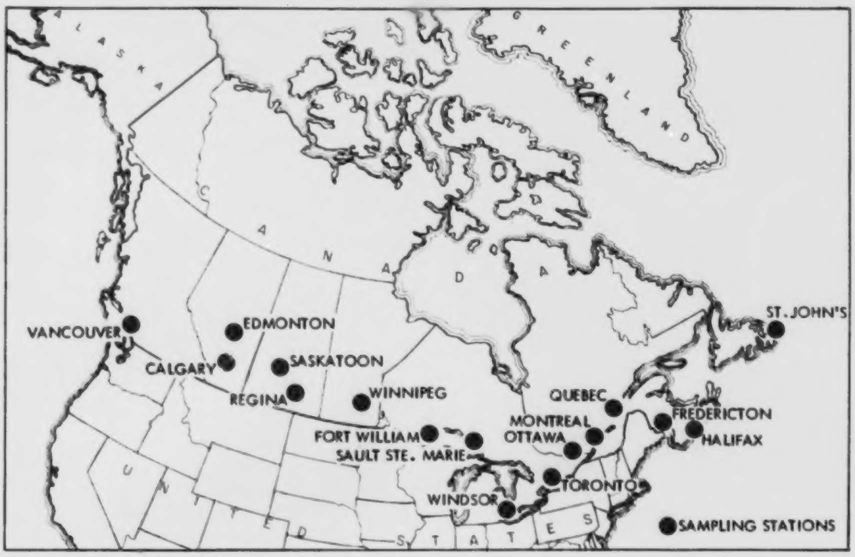
ALASKA
GREENLAND
CANADA
UNITED STATES
VANCOUVER
EDMONTON
CALGARY
SASKATOON
REGINA
WINNIPEG
FORT WILLIAM
SAULT STE. MARIE
WINDSOR
TORONTO
OTTAWA
MONTREAL
QUEBEC
FREDERICTON
HALIFAX
ST. JOHN'S
SAMPLING STATIONS

Figure 3. Canadian milk sampling stations

---

[1] Prepared from July 1968 monthly report "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

3. Pan American Milk Sampling Program June 1968

Pan American Health Organization and *U.S. Public Health Service*

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American Republics in developing national radiological health programs.

Under a joint agreement between agencies, air and milk sampling activities are conducted by a number of PAHO-member countries (figure 4). Results of the milk sampling program are presented below. Further information on the sampling and analytical procedures employed was presented in the December 1966 issue of *Radiological Health Data and Reports* (5).

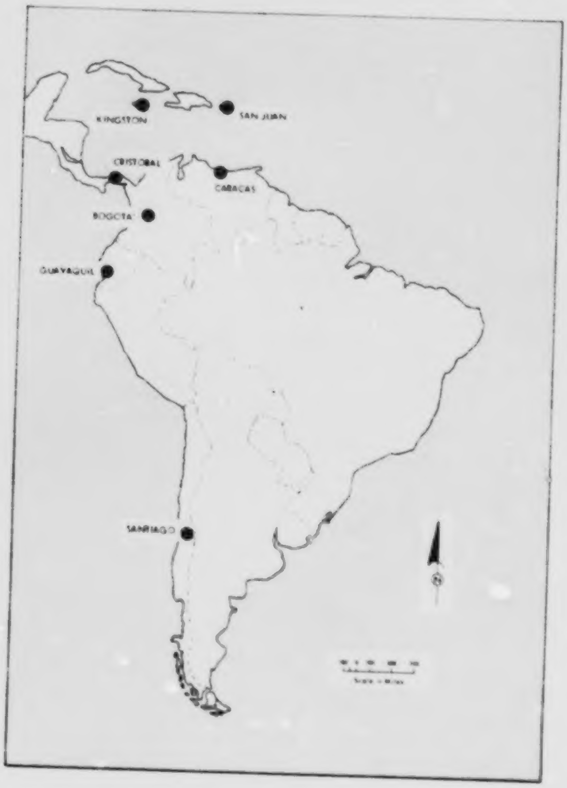

Figure 4. Pan American Milk Sampling Program stations

Table 4 presents stable potassium, strontium-90 and cesium-137 monthly concentrations for June 1968.

Table 4. Stable element and radionuclide concentrations in Pan American milk[a], June 1968

Sampling station	Number of samples	Potassium g/liter	Strontium-90 [b] (pCi/liter)	Cesium-137 [b] (pCi/liter)
Chile: Santiago	1	1.5	0	0
Colombia: Bogota	1	1.5	0	0
Ecuador: Guayaquil	1	1.6	0	0
Jamaica: Montego Bay	1	1.4	8	170
Venezuela: Caracas	1	1.5	0	0
Canal Zone: Cristobal [c]	4	1.5	0	6
Puerto Rico: San Juan	4	1.6	6	14

[a] All strontium-89 results were ≤5 pCi/liter; iodine-131 and barium-140 results were all ≤10 pCi/liter.

[b] Strontium-90 single sample results ≤2 pCi/liter and cesium-137 single sample results ≤10 pCi/liter are reported as 0.

[c] For comparison, the average radionuclide concentrations in Pasteurized Milk Network samples collected at Cristobal, Canal Zone, and San Juan, Puerto Rico, are presented.

REFERENCES

(1) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, September 1967. Radiol Health Data Rep 9:20–23 (January 1968).

(2) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, October 1967. Radiol Health Data Rep 9:86–89 (February 1968).

(3) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1960).

(4) DEPARTMENT OF NATIONAL HEALTH AND WELFARE, RADIATION PROTECTION DIVISION. Canadian milk network, August 1966. Radiol Health Data Rep 7:702–703 (December 1966).

(5) PAN AMERICAN HEALTH ORGANIZATION and U.S. PUBLIC HEALTH SERVICE. Pan American Milk Sampling Program, August 1966. Radiol Health Data Rep 7:704–705 (December 1966).

State Milk Surveillance Activities

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States now have comprehensive environmental surveillance programs and self-sustaining radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes. The results presented herein are representative of current surveillance activities directed at the use of milk as an indicator of dietary intake of radioactivity.

Figure 1 shows the States which report milk surveillance activities in *Radiological Health Data and Reports.* States having programs appearing in this issue are highlighted in the figure. Following is a summary of previously covered State programs, their reporting period, and the last issue in which they appeared.

State milk network	Period reported	Last presented
California	January–March 1968	September 1968
Connecticut	January–March 1968	August 1968
Indiana	January–March 1968	August 1968
Iowa	January–March 1968	August 1968
Michigan	January–March 1968	August 1968
Minnesota	January–March 1968	August 1968
New York	January–March 1968	August 1968
Oklahoma	September–December 1967	April 1968
Oregon	January–March 1968	September 1968
Pennsylvania	January–March 1968	August 1968
Washington	January–March 1968	September 1968

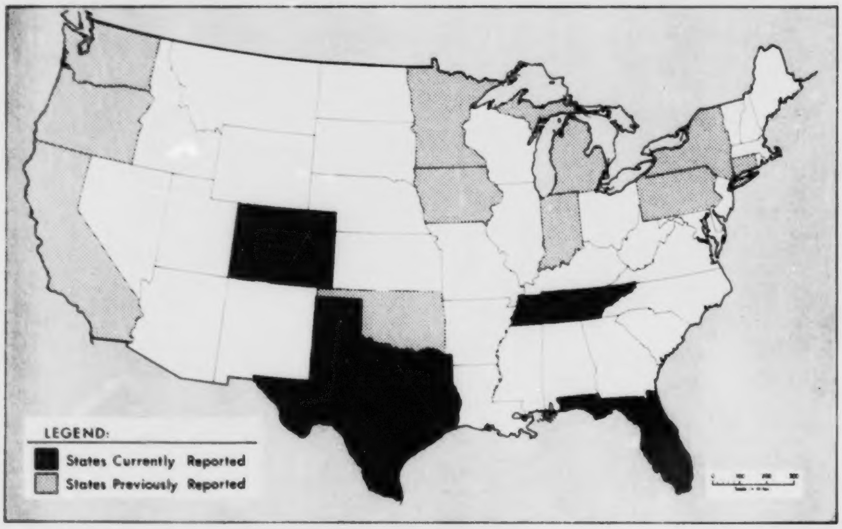

Figure 1. Reported State milk programs

29

1. Colorado Milk Network
April–June 1968

Air, Occupational and Radiation
Hygiene Division
Colorado State Department of Public Health

The Radiation Hygiene Section of the Colorado State Health Department initiated analysis of milk for gamma-ray emitting radionuclides in January, 1962. Initially a composite milk sample from the major producers supplying the Denver area was collected by the Denver City and County Health Department for the State.

In August 1962, the State expanded this program to include the sampling of raw milk from the major milk producing areas supplying the entire State. The routine sampling rate depends on the activities of the Milk, Food and Drug Section of the State Health Department. Milkshed areas are shown in figure 2.

Analyses are performed for iodine–131, cesium–137, barium-lanthanum–140 and potassium by gamma-ray spectrometry. Employed in this procedure is a 4- by 5-inch diameter NaI (Tl) crystal housed in a modified office safe lined with 2 inches of lead and a 512 multichannel pulse-height analyzer using a typewriter readout. Samples and backgrounds are counted for 40 minutes in a 2 quart (1,892 ml) plexiglass Marinelli beaker. Calculation is by the matrix method (*1*) and the minimum detectable concentrations are: iodine–131, 15 pCi/liter; cesium–137, 16 pCi/liter; barium-lanthanum–140, 16 pCi/liter; and potassium, 0.25 g/liter.

Eleven milk samples were collected and counted during the period from April 1 to June 30, 1968. Iodine–131, cesium–137 and barium-lanthanum–140 were below the respective minimum detectable concentrations in all but three samples from area 4 (figure 2). These concentrations were 30 pCi/liter in two samples for iodine–131. The third sample concentrations for iodine–131 and barium-lanthanum–140 were each 16 pCi/liter. Potassium concentrations averaged 1.4 ± 0.2 (2σ) g/liter.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	April 1968
January–March 1968	July 1968

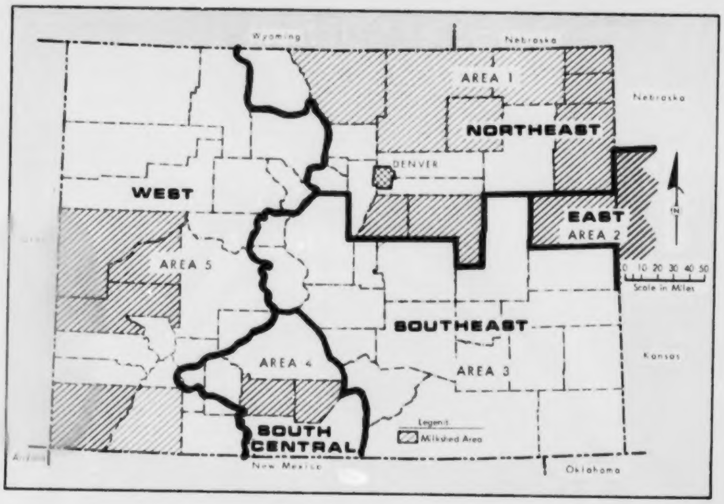

Figure 2. Colorado milk sampling stations

2. Florida Milk Network
April–June 1968

Division of Radiological Health
Florida State Board of Health

The Florida State Board of Health began sampling raw milk for iodine–131 analysis in two major areas of the State in November 1962. The program has since been expanded to include the analysis of milk for strontium–90, cesium–137, barium–140 and potassium, in addition to iodine–131. Analysis for strontium–89 was made until 1965 but due to extremely low levels has been discontinued since that time. Monthly sample collection procedures for obtaining milk from randomly selected farms in each of the six regions of the State was redesigned in July 1968 (figure 3). Beginning in July 1968, a 1-gallon raw milk sample is collected monthly from a major processing plant in each of the regions referenced above. The milk produced in each region is generally processed and consumed in that region. The processing plant from which the milk sample is obtained was selected on its percentage contribution to the total milk market.

The sample of milk is collected in each region on Monday or Tuesday following the first Sunday of each month. The maximum age of any portion of the milk making up the sample is 72 hours. The samples are sent to the State Board of Health Radiological Laboratory in Orlando for analyses. The samples are analyzed and corrected for decay to the time and date of collection.

Strontium–90 is determined by the ion exchange method developed by Porter et al. (*2*). Iodine–131, cesium–137, barium–140 and potassium are determined by gamma-ray spectrometry (*3*).

Radionuclide concentration levels for April through June 1968, are presented in table 1.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	April 1968
January–March 1968	July 1968

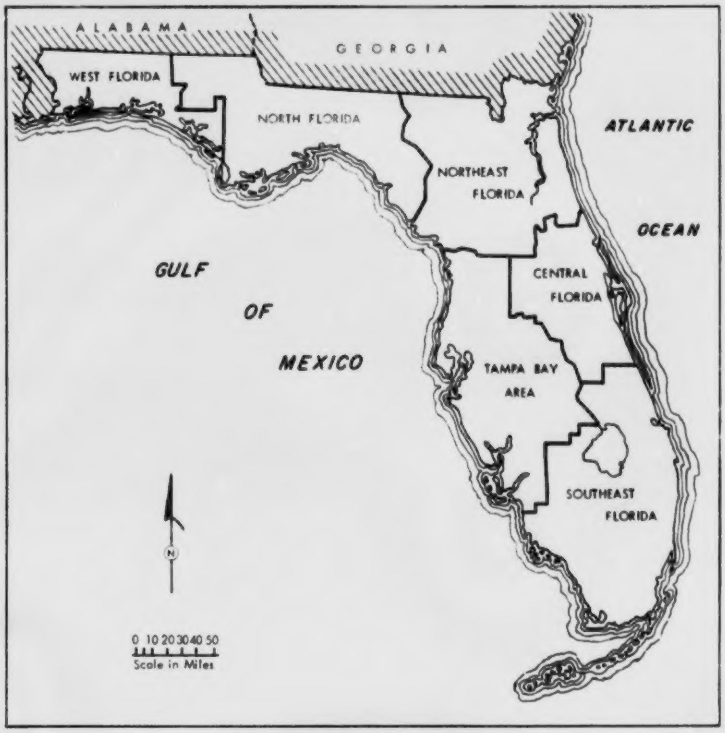

Figure 3. Florida milk sampling areas

Table 1. Stable element and radionuclide concentrations in Florida raw milk, April-June 1968

Sampling location	Potassium (g/liter)			Strontium-90 (pCi/liter)			Iodine-131 (pCi/liter)			Cesium-137 (pCi/liter)			Barium-140 (pCi/liter)		
	April	May	June	April	May	June	April	May	June	April	May	June	April	May	June
West	1.3	1.6	1.4	14	17	17	ND	ND	25	ND	45	21	ND	27	<20
North	1.4	1.7	NS	14	15	NS	ND	ND	NS	ND	43	NS	ND	ND	NS
Northeast	1.5	1.7	1.5	6	NA	10	ND	28	<20	130	93	76	58	30	23
Central	NS	NS	1.6	NS	NA	13	NS	NS	<20	NS	NS	89	NS	NS	<20
Tampa Bay area	1.4	1.5	1.6	7	7	6	ND	ND	<20	55	99	77	ND	ND	<20
Southeast	1.4	1.6	1.5	9	8	8	ND	ND	<20	72	92	89	ND	23	<20

NA, no analysis.
ND, nondetectable.
NS, no sample.

3. Tennessee Milk Network April–June 1968

Division of Preventable Diseases
Department of Public Health,
State of Tennessee

The Tennessee Department of Public Health began sampling pasteurized milk for radionuclide analysis in July of 1965. Currently the Department is collecting semimonthly milk samples from four cities (figure 4). In order to obtain a representative sample of the milk consumed in the areas monitored, a sample of milk is collected from each milk distributor supplying the city. The samples from the individual distributors are then composited in proportion to the contribution each makes to the total city milk supply.

Analytical procedures

The semimonthly milk samples from each city sampled are analyzed by gamma-ray scintillation spectrometry for potassium–40, iodine–131, cesium–137, and barium–140, using a 3½-liter sample (*4*). After gamma-ray analysis, the samples are stored for 2 weeks to allow ingrowth of daughter radioactivity, after which strontium–89, strontium–90, and barium–140 concentrations are determined radiochemically using ion-exchange procedures (*5*). Chemical analyses are also made for stable calcium and potassium.

The Chattanooga milk sample is monitored by both the State and the Public Health Service's Southeastern Radiological Health Laboratory. This dual examination of aliquot samples provides a cross-check between the two laboratories.

Results

The monthly average stable element and radionuclide concentrations in Tennessee pasteurized milk are presented in table 2 for the period of April through June 1968.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	April 1968
January–March 1968	July 1968

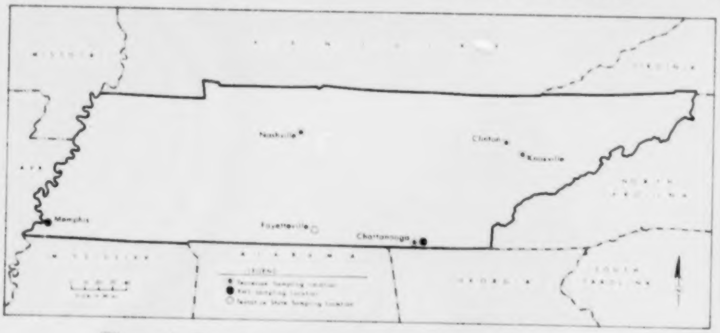

Figure 4. Tennessee pasteurized milk sampling stations

Table 2. Radionuclides in Tennessee pasteurized milk, April-June 1968

Location	Month 1968	Concentration (g/liter)	Radionuclide concentration (pCi/liter)				
		Potassium	Strontium 89	Strontium 90	Iodine-131	Cesium-137	Barium-140
Chattanooga	April	1.6	<5	14	<9	21	<8
	May	1.4	NA	NA	<9	20	<8
	June	1.5	10	12	<9	27	<8
Clinton	April	1.6	<5	20	<9	29	<8
	May	1.4	NA	NA	<9	21	<8
	June	1.6	11	14	<9	29	<8
Knoxville	April	1.5	<5	13	11	30	<8
	May	1.5	NA	NA	<9	23	<8
	June	1.4	5	10	<9	19	13
Nashville	April	NS	NS	NS	NS	NS	NS
	May	1.6	<5	NA	<9	22	<8
	June	1.5	<5	10	<9	14	<8

NA, no analysis.
NS, no sample.

4. Texas Milk Network
April–June 1968

Texas State Department of Health[2]

The Texas State Department of Health initiated a Statewide milk sampling network for radionuclide content in April 1964. At present, samples of raw milk are collected from each of twelve sampling points once each calendar quarter. The station locations shown in figure 5 were chosen to give maximum geographical and population coverage.

Samples are routinely analyzed for strontium-90 by a chemical separation technique employing ion exchange columns (*6*). Prepared samples are counted for 100 minutes in a low-background beta-particle counter.

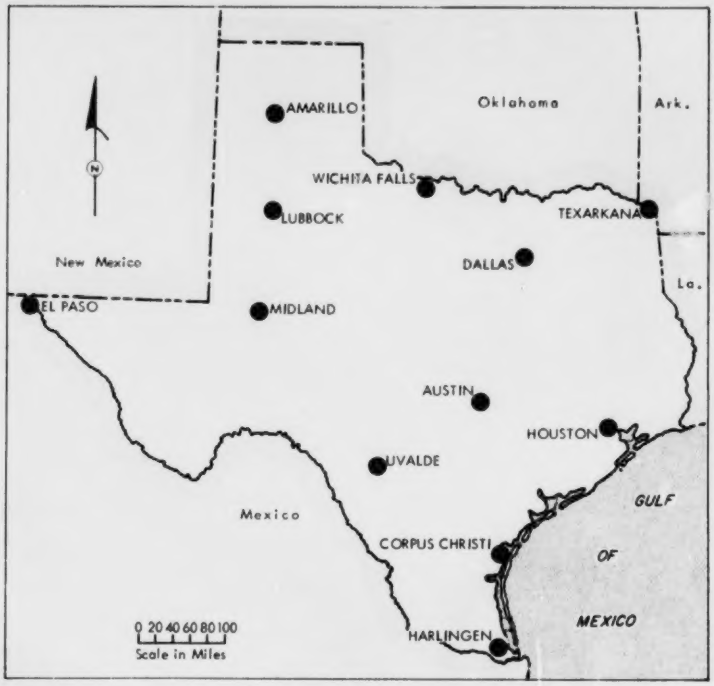
AMARILLO
Oklahoma
Ark.
N
WICHITA FALLS
LUBBOCK
TEXARKANA
New Mexico
DALLAS
La.
EL PASO
MIDLAND
AUSTIN
HOUSTON
UVALDE
GULF
Mexico
CORPUS CHRISTI
OF
MEXICO
0 20 40 60 80 100
Scale in Miles
HARLINGEN

Figure 5. Texas milk sampling stations

---

[2] Acknowledgement is accorded to the staff of the Radiation Control Program, Division of Occupational Health and Radiation Control, under the direction of Mr. Martin C. Wukasch, chief engineer.

33

Potassium–40, iodine–131, cesium–137 and barium–140 concentrations are determined by gamma-ray spectrometry. The procedure employs a 4- by 4-inch sodium iodide crystal and a 400-channel analyzer. Samples are counted for 100 minutes in a 3.5 liter Marinelli beaker. The matrix method of calculation is used and detection limits at the 95-percent confidence level are 10 pCi/liter.

Results

Potassium, strontium–90 and cesium–137 results by station and month for April through June 1968 are presented in table 3. During this time, the iodine–131 and barium–140 concentrations were below their limits of detectability (10 pCi/liter). A summary of radionuclide concentrations in Texas milk for the period from April 1964 through June 1968 is presented in figure 6.

Table 3. Radionuclide concentrations in Texas raw milk network,[a] April-June 1968

Sampling location	Potassium (g/liter)			Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)		
	Apr	May	June	Apr	May	June	Apr	May	June
Amarillo	—	—	1.3	—	—	3	—	—	[b] <10
Corpus Christi	—	1.5	—	—	5	—	—	10	—
El Paso	—	1.4	—	—	3	—	—	<10	
Fort Worth	1.5	—	—	10	—	—	10	—	—
Harlingen	—	—	1.6	—	—	2	—	—	<10
Houston	—	1.5	—	—	13	—	—	20	—
Lubbock	NA								
Midland	1.6	—	—	4	—	—	<10	—	—
San Antonio	—	—	1.5	—	—	2	—	—	<10
Texarkana	—	—	1.5	—	—	12	—	—	15
Uvalde	1.5	—	—	3	—	—	<10	—	—
Wichita Falls	NA								

[a] Samples collected on a quarterly frequency at each sampling location.
[b] Below detectable limits.
NA, no analysis.

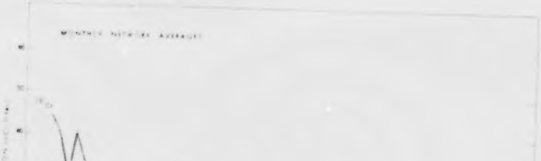

Figure 6. Radionuclide concentrations in Texas milk April 1964–June 1968

Comparison of the observed radionuclide concentrations with the Federal Radiation Council guides for peacetime operation indicates that at no time during the period of surveillance did the radionuclide concentrations in Texas milk approach levels suggesting any remedial action (*7*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	April 1968
January–March 1968	July 1968

REFERENCES

(*1*) COLORADO STATE DEPARTMENT OF PUBLIC HEALTH, OCCUPATIONAL AND RADIOLOGICAL HEALTH DIVISION. Colorado milk network, October–December 1964 and summary 1962–1964. Radiol Health Data 6:202–204 (April 1965); January 1965–June 1966. Radiol Health Data Rep 7:573–575 (October 1966).

(*2*) PORTER, C., D. CAHILL, R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Improved determination of strontium–90 in milk by ion-exchange method. Anal Chem 33:1306–1309 (September 1961).

(*3*) FLORIDA STATE BOARD OF HEALTH, DIVISION OF RADIOLOGICAL HEALTH. Florida milk network, July–December 1964. Radiol Health Data 6:611–612 (November 1965).

(*4*) PORTER, C., R. AUGUSTINE, J. MATUSEK, JR., and M. CARTER. Procedures for Determining Stable Nuclides in Environmental Samples. PHS No. 999–RH–10. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (January 1965).

(*5*) PORTER, C., M. CARTER, B. KAHN, and E. PEPPER. Rapid Field Method for the Collection of Radionuclides from Milk. Proceedings of the First International Congress of the International Radiation Protection Association held in Rome, Italy, September 5–10, 1966 (in press).

(*6*) PORTER, C., and B. KAHN. Improved determination of strontium–90 in milk by ion exchange method. Anal Chem 36:676–678 (March 1964).

(*7*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

34

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

Program	Period reported	Last presented
California Diet Study	July–October 1967	May 1968
Connecticut Standard Diet	July–December 1967	May 1968
Tri-City Diet, HASL	April–December 1967	June 1968

---

1. Radionuclides in Institutional Diet Samples January–March 1968

National Center for Radiological Health and *National Center for Urban and Industrial Health, PHS*

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiological surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service initiated its Institutional Diet Sampling Program in 1961. This program is administered by the National Center for Radiological Health with the assistance of the National Center for Urban and Industrial Health (*1*).

The program was designed to provide estimates of the dietary intake of radionuclides in a selected population group ranging from children to young adults of school age. Initially, the program was conducted at eight institutions; as of January 1965, its scope had increased to boarding schools or institutions in 50 municipalities. These institutions ranged from financially well-to-do boarding schools to orphanages with severe economic limitations.

Subsequent experience with the diets of school children of various ages indicated that the number of institutions sampled could be selectively reduced. As of July 1965, 21 basic institutions and 8 auxiliary institutions, distributed geographically as shown in figure 1, were being sampled. Previous results showed that the daily dietary intake of teenage girls and children from 9 to 12 years of age were comparable, while teenage boys consumed 20 percent more food per day (*1, 2*). Consequently, estimates for boys and/or girls can be calculated on the basis of the dietary intakes of children.

Sampling procedures

In general, the sampling procedure is the same at each institution. Each sample represents the edible portion of the diet for a full 7-day week (21 meals plus soft drinks, candy bars, or other in-between snacks), obtained by duplicating the meals of a different individual each day. Each daily sample is kept frozen until the end of the collection period and is then packed in dry ice and shipped by air express to either the Southwestern Radiological Health Laboratory, Las Vegas, Nev.; the Southeastern Radiological Health Laboratory, Montgomery, Ala.; or the Northeastern Radiological Health Laboratory, Winchester, Mass.

The sample for each day is packaged in three parts: (1) solid food and semisolid food minus those portions that would not ordinarily be eaten; (2) liquid milk; (3) other beverages such as soft drinks, coffee, and tea. Drinking water is not included in these samples. A record of the contents of each meal and the approximate amount of each item is made at the institution and sent with the sample.

35

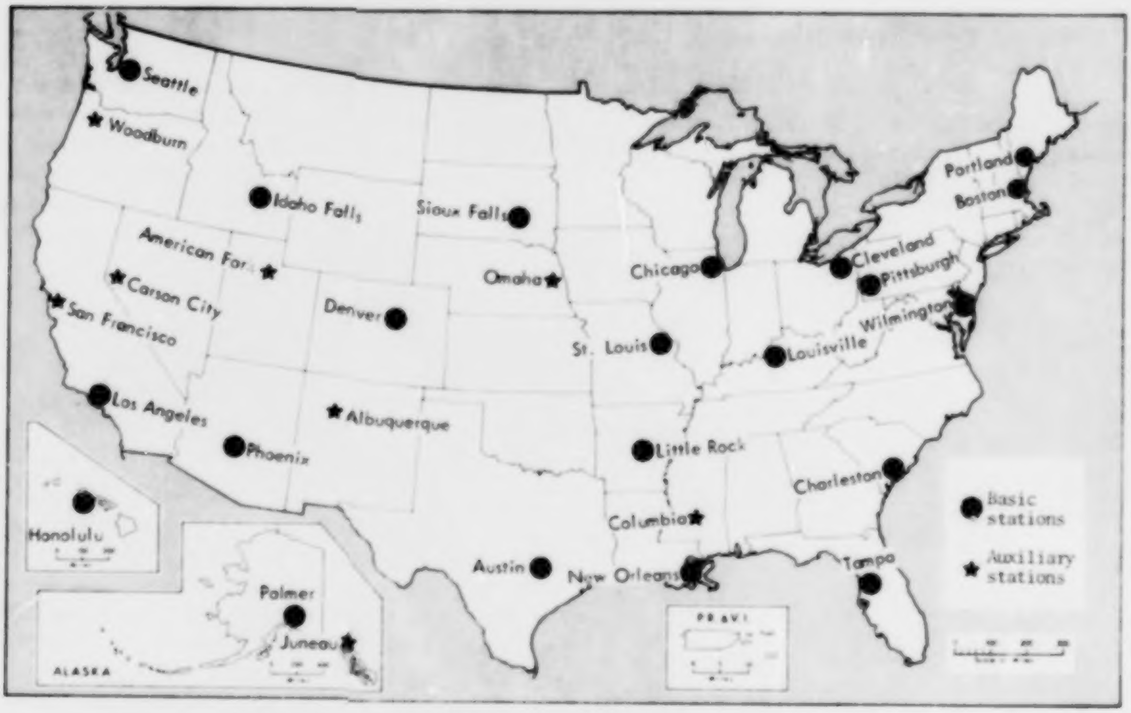
Seattle
Woodburn
Idaho Falls
Sioux Falls
American For.
Carson City
San Francisco
Omaha
Chicago
Cleveland
Pittsburgh
Portland
Boston
Wilmington
Denver
St. Louis
Louisville
Los Angeles
Albuquerque
Phoenix
Little Rock
Charleston
Honolulu
Columbia
Austin
New Orleans
Tampa
Palmer
Juneau
ALASKA
P.R. & V.I.
Basic stations
Auxiliary stations

Figure 1. Institutional diet sampling locations as of March 1968

A water sample is collected once a year and analyzed from each institution. For each new institution a water sample is collected and analyzed each quarter for the first year and then once a year subsequently. If an institution is not in a milkshed of the Pasteurized Milk Network, a special milk sample is collected monthly.

Analytical procedures

When the samples arrive at the laboratory, an identification number is assigned to each weekly sample. Total weight is accurately determined. Sample volumes usually range from 6 to 16 liters; sample weights range from 8 to 20 kilograms. A commercial blender or specially constructed homogenizer is used to make the sample homogeneous so that aliquots will be identical in composition. Portions of the slurry are measured into appropriate containers for analysis by gamma spectrometry and/or for ashing prior to radiochemical analysis.

Stable calcium is measured because calcium compounds may influence the uptake of bone-seeking radionuclides such as radiostrontium. Stable potassium is measured as it provides a handy reference point for the analysis. An unusual concentration of potassium-40 and therefore of stable potassium indicates something is wrong with the analysis, with the sample, or with both.

Stable calcium is analyzed by the permanganate titration procedure after an aliquot of the sample is ashed. Stable potassium, iodine-131, barium-140 and cesium-137 are analyzed by gamma spectrometry. Strontium-89 and strontium-90 are analyzed by chemical separation or ion exchange techniques. Radium-226 is analyzed by the radon-222 emanation method. The details of these analyses can be found in the NCRH document entitled "Radioassay Procedures for Environmental Samples" (*3*).

Results

Table 1 presents the analytical results for institutional diet samples collected from January through March 1968, for children 9 to 12 years of age. The stable elements, calcium and

Table 1. Concentrations and intake of stable elements and radionuclides in Institutional total diets of children (9-12 years of age), January-March 1968

Location of Institution		Month	Total weight (kg/day)	Calcium		Potassium		^{90}Sr		^{137}Cs		^{226}Ra	
				g/kg	g/day	g/kg	g/day	pCi/kg	pCi/day	pCi/kg	pCi/day	pCi/kg	pCi/day
Alaska:	Palmer	Jan	1.58	0.9	1.4	1.4	2.3	6	9	11	17	0.4	0.6
		Feb	1.63	.6	1.0	1.3	2.1	15	25	18	29	.4	.6
		Mar	2.11	.6	1.2	1.3	2.8	5	10	0	0	.5	1.1
Ariz:	Phoenix	Jan	2.56	.6	1.6	1.2	3.0	5	13	12	31	.4	1.0
		Feb	2.18	.5	1.1	1.2	2.6	5	10	0	0	.3	.6
		Mar	1.45	.4	0.6	1.2	1.7	0	0	18	26	.3	.4
Ark:	Little Rock	Jan	1.89	.6	1.2	1.8	3.4	12	23	16	30	.6	1.1
		Feb	1.67	.6	1.1	1.5	2.6	12	21	11	18	.7	1.2
		Mar	1.81	.6	1.1	1.6	2.9	7	13	0	0	.4	.7
Calif:	Los Angeles	Jan *	1.61	.5	.8	1.3	2.2	5	9	14	23	.8	1.3
		Feb	1.57	.5	.8	1.4	2.2	5	8	0	0	.6	.9
		Mar *	1.95	.5	1.0	1.3	2.5	5	10	14	27	.6	1.2
Colo:	Denver	Jan *	2.30	.8	1.7	1.2	2.8	6	13	11	25	.5	1.2
		Feb	2.05	.7	1.4	1.5	3.1	7	11	0	0	.5	1.0
		Mar	2.35	.8	1.9	1.6	3.8	4	10	18	42	.7	1.4
Del:	Wilmington	Jan	2.01	.8	1.5	1.8	3.6	10	21	13	26	.4	.8
		Feb	2.14	.6	1.3	1.7	3.6	8	16	0	0	.4	.9
		Mar	2.11	.8	1.6	1.7	3.6	8	18	0	0	.9	1.9
Fla:	Tampa	Jan	1.78	.4	.8	1.7	3.0	6	10	34	60	.7	1.2
		Feb	2.16	.6	1.2	1.8	4.0	10	21	31	67	.7	1.5
		Mar	2.20	.6	1.2	2.0	4.0	8	18	32	70	.4	.9
Hawaii:	Honolulu	Jan	1.90	.5	.9	1.4	2.7	2	5	20	38	.4	.8
		Feb	2.19	.5	1.1	1.4	3.0	2	5	15	33	.4	.9
		Mar	2.48	.5	1.2	1.4	3.5	3	7	18	45	.4	1.0
Idaho:	Idaho Falls	Jan *	2.30	1.3	2.9	1.8	4.1	13	30	12	27	.4	.9
		Feb *	2.25	1.0	2.3	1.7	3.8	7	16	0	0	.6	1.3
		Mar *	1.91	.9	1.7	1.4	2.6	10	18	18	34	.5	.9
Ill:	Chicago	Jan	1.62	.7	1.2	1.6	2.6	6	10	18	29	.6	1.0
		Feb *	1.53	.7	1.1	1.5	2.3	7	10	15	23	.8	1.2
		Mar	1.57	.8	1.6	1.8	2.8	6	9	22	34	.6	.9
Ky:	Louisville	Jan	1.35	.8	1.0	1.9	2.6	8	10	0	0	.5	.7
		Feb	1.73	.7	1.3	1.6	2.8	7	12	14	24	.4	.7
		Mar	1.39	.5	.8	1.5	2.1	7	10	0	0	.6	.8
La:	New Orleans	Jan	1.86	.8	1.5	1.6	3.0	14	25	20	37	.5	.9
		Feb	2.14	.8	1.7	1.8	3.8	17	37	14	30	.5	1.1
		Mar	1.90	.7	1.3	1.8	3.4	12	23	14	27	.5	1.0
Mass:	Boston	Jan	1.82	.7	1.3	1.5	2.8	8	15	17	31	.6	1.1
		Feb	1.51	.7	1.0	1.4	2.1	7	10	16	24	.5	.8
		Mar	1.68	.7	1.3	1.3	2.2	10	13	19	32	.4	.7
Mo:	St. Louis	Jan	2.49	.9	2.3	1.7	4.3	9	23	0	0	.8	2.0
		Feb	2.63	1.1	3.0	1.8	4.6	9	24	25	66	1.0	2.6
		Mar	2.59	1.2	3.2	1.8	4.5	10	27	12	31	1.1	2.8
Ohio:	Cleveland	Jan	1.42	.6	1.0	1.8	2.5	8	12	18	26	.7	1.0
		Feb	1.73	.6	1.1	1.7	3.0	9	15	24	42	.7	1.2
		Mar	1.15	.7	.8	1.8	2.0	10	11	18	21	.7	.8
Pa:	Pittsburgh	Jan	2.22	.6	1.3	1.5	3.4	9	20	0	0	.8	1.8
		Feb	2.27	.5	1.2	1.4	3.1	9	19	23	52	.7	1.6
		Mar	2.19	.6	1.3	1.4	3.1	8	18	12	26	.6	1.3
S. C.:	Charleston	Jan *	2.10	.8	1.7	1.3	2.8	10	21	22	46	1.4	2.9
		Feb	1.45	.6	.8	1.6	2.4	7	11	16	23	.7	1.0
		Mar	1.39	.8	1.1	1.7	2.4	11	16	21	29	1.1	1.5
S. Dak:	Sioux Falls	Jan	1.23	1.2	1.4	1.6	2.0	17	21	11	13	.7	.9
		Feb	1.21	.7	.8	1.4	1.7	5	6	0	0	.7	.8
		Mar	1.14	.8	.9	1.6	1.9	8	9	18	20	1.0	1.1
Tex:	Austin	Jan	1.73	.5	.9	1.3	2.2	5	8	0	0	.5	.9
		Feb	1.79	.6	1.0	1.5	2.8	5	9	26	46	.6	1.1
		Mar	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Maine:	Portland	Jan	1.55	.9	1.3	1.7	2.6	15	24	25	39	.9	1.4
		Feb	1.48	.8	1.2	1.7	2.5	13	20	35	52	.8	1.1
		Mar	1.49	.9	1.4	1.6	2.3	13	20	16	24	.6	.9
Wash:	Seattle	Jan *	1.71	.5	.8	1.7	2.9	4	7	16	27	.5	.9
		Feb *	2.20	.4	.9	1.3	2.9	4	9	0	0	.5	1.1
		Mar *	1.75	.5	.9	1.7	3.0	6	11	0	0	.7	1.2
Institutional average		Jan	1.81	.7	1.3	1.6	2.9	9	16	13	24	0.6	1.1
		Feb	1.86	.6	1.2	1.5	2.9	8	16	15	28	0.6	1.1
		Mar	1.82	.7	1.3	1.6	2.9	8	14	14	25	0.6	1.1

* Since food samples were collected from two or more children who were not between the ages of 9-12, data for this month were not used in institutional average.

NS, no sample.

Note: Since iodine-131, barium-140 and strontium-89 were not detectable at most stations during the first quarter of 1968, no provision was made for the nuclides in the table. The few exceptions are as follows: barium-140 was reported in January for Louisiana, 14 pCi/kg. Barium-140 was also reported in March for Idaho, 17 pCi/kg. Strontium-89 was reported in January for Colorado, 6 pCi/kg.

potassium, are reported in g/k of diet and the radionuclide concentrations of these samples, reported in pCi/kg of diet, are corrected for radioactive decay to the midpoint of the sample collection period, where applicable. Dietary intakes, in g/day or pCi/day, were obtained by multiplying the food consumption rate in kg/day by the appropriate concentration values. The average food consumption rate during this period was 1.83 kg/day compared to the network average of 1.86 kg/day observed from 1961 through 1967.

Strontium-90 dietary intake during this period averaged 15 pCi/day. This result falls within Range I as defined by the Federal Radiation Council (4). Cesium-137 intakes averaged 27 pCi/day during this period. Strontium-89, iodine-131 and barium-140 concentrations were generally below detectable levels.

All concentrations that are less than or equal to the appropriate minimum detectable level will be reported as zero. The minimum detectable concentration is defined as the measured concentration equal to the two-standard deviation analytical error. Accordingly, the minimum detectable limits are as follows:

Strontium-89	5 pCi/kg
Strontium-90	2 pCi/kg
Iodine-131	10 pCi/kg
Cesium-137	10 pCi/kg
Barium-140	10 pCi/kg
Radium-226	0.1 pCi/kg

Data from eight auxiliary stations are included in a separate table (table 2) for general information. These stations do not meet the criterion that the majority of the samples are collected from individuals who range in age from 9–12 years. In order to supplement the existing environmental monitoring networks of the National Center for Radiological Health, these eight institutions are being sampled in the same manner as the basic stations.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
April–June 1967	January 1968
July–September 1967	April 1968
October–December and Annual Summary 1967	July 1968

REFERENCES

(1) ANDERSON, E. C., and D. J. NELSON, JR. Surveillance for radiological contamination in foods. Amer J Public Health 52:1391–1400 (September 1962).

(2) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, January–March 1965. Radiol Health Data 6:548–554 (October 1965).

(3) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Radioassay Procedures for Environmental Samples, PHS Publication No. 999-RH-27. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (January 1967).

(4) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Table 2. Concentrations and intake of stable elements and radionuclides in Institutional total diets of individuals (auxilliary stations), January-March 1968

Location of Institution		Month	Total weight (kg/day)	Calcium		Potassium		^{90}Sr		^{137}Cs		^{226}Ra	
				g/kg	g/day	g/kg	g/day	pCi/kg	pCi/day	pCi/kg	pCi/day	pCi/kg	pCi/day
Alaska:	Juneau	Jan.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		Feb.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		Mar.	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Calif:	San Francisco	Jan.	2.63	0.7	1.8	1.8	4.8	3	8	0	0	0.5	1.3
		Feb.	2.83	.6	1.7	1.5	4.2	3	8	13	37	.5	1.4
		Mar.	1.92	.7	1.3	1.7	3.3	8	16	14	27	.7	1.3
Miss:	Columbia	Jan.	1.75	.8	1.4	1.7	2.9	12	21	20	35	.5	0.9
		Feb.	2.17	1.0	2.2	1.6	3.5	12	26	12	26	.7	1.5
		Mar.	1.92	1.0	1.9	1.6	3.0	10	19	15	29	.6	1.2
Nebr:	Omaha	Jan.	2.31	.8	1.9	1.7	4.0	8	18	0	0	1.2	2.8
		Feb.	2.54	1.0	2.6	1.6	4.1	7	17	11	28	1.8	4.6
		Mar.	2.16	.8	1.8	1.4	3.1	6	12	12	26	.9	1.9
Nev:	Carson City	Jan.	1.79	.5	0.9	1.1	2.0	7	13	0	0	.3	.5
		Feb.	1.45	.7	1.0	1.5	2.1	6	9	0	0	.8	1.2
		Mar.	1.61	.6	1.0	1.5	2.4	5	7	18	29	.6	1.0
Ore:	Portland	Jan.	2.45	.7	1.7	1.9	4.8	9	23	11	27	.6	1.5
		Feb.	2.34	.4	.9	[illegible]	6.0	5	13	23	54	.3	.7
		Mar.	2.44	.5	1.2	2.0	4.8	5	13	35	85	.5	1.2
N. Mex:	Albuquerque	Jan.	2.24	.8	1.9	1.6	3.6	4	9	0	0	.4	.9
		Feb.	2.22	.8	1.8	1.8	4.0	4	9	0	0	.3	.7
		Mar.	2.41	.5	1.3	1.1	2.7	5	12	0	0	.7	1.7
Utah:	Salt Lake City	Jan.	2.15	.7	1.4	1.3	2.7	4	8	16	34	.5	1.1
		Feb.	2.08	.5	1.1	1.2	2.4	6	12	0	0	.5	1.0
		Mar.	1.86	.5	.9	1.2	2.2	4	8	0	0	.5	.9
Institutional average		Jan.	2.19	0.7	1.6	1.6	3.5	7	14	7	14	0.6	1.3
		Feb.	2.23	0.7	1.6	1.7	3.8	6	13	8	21	0.7	1.6
		Mar.	2.05	0.7	1.3	1.5	3.1	6	12	13	28	0.6	1.3

NS, no sample.

Note: Since iodine-131, barium-140, and strontium-89 were not detected at most stations during the first quarter of 1968, no provision was made for these nuclides in the table. The few exceptions are as follows: barium-140 was reported in March for Nebraska, 12 pCi/kg. Strontium-89 was reported in January for Oregon, 9 pCi/kg.

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

Water sampling program	Period reported	Last presented
California	January–June 1967	June 1968
Colorado River Basin	1965–1966	May 1968
Coast Guard	January–December 1966	November 1967
Radiostrontium in Tap Water, HASL	July–December 1967	June 1968
Florida	1965–1966	July 1968
Washington	July 1966–June 1967	August 1968

---

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, Revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Gross Radioactivity in Surface Waters of the United States, April 1968

Division of Pollution Surveillance
Federal Water Pollution Control Administration
Department of the Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as part of the Federal Water Pollution Control Administration's Water Pollution Surveillance System. Table 1 presents the current preliminary results of the alpha and beta radioanalyses. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium-90 results are reported semiannually. The stations on each river are arranged in the table according to their distance from the headwaters. Figure 1 indicates the average total beta radioactivity in suspended-plus-dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the August 1967 issue of *Radiological Health Data and Reports.*

Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

Special note is taken when the alpha radioactivity concentration is 15 pCi/liter or greater or when the beta radioactivity concentration is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data for comment. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted

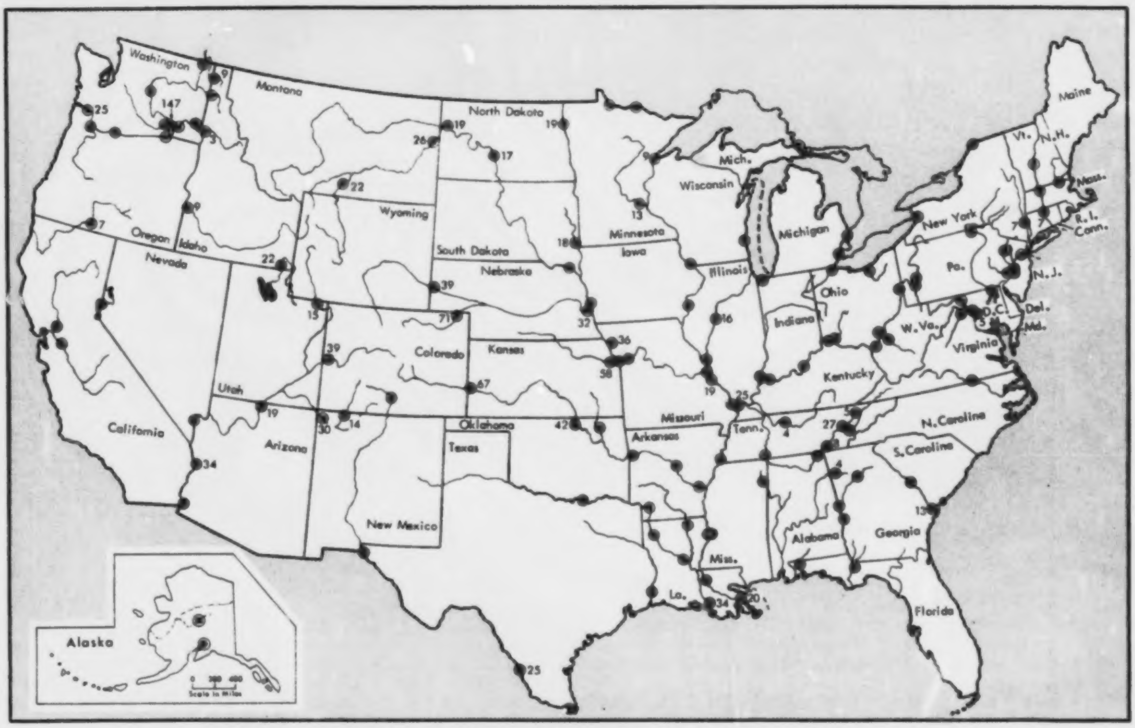
Washington
Montana
North Dakota
Maine
Vt.
N.H.
Mass.
R.I.
Conn.
Mich.
Wisconsin
Minnesota
Michigan
New York
Oregon
Idaho
Wyoming
South Dakota
Nevada
Nebraska
Iowa
Illinois
Pa.
N.J.
Ohio
Indiana
D.C.
Del.
Md.
W.Va.
Virginia
Colorado
Kansas
Utah
Kentucky
California
Missouri
Oklahoma
Arizona
Tenn.
N.Carolina
Arkansas
Texas
S.Carolina
New Mexico
Alabama
Georgia
Miss.
La.
Florida
Alaska
Scale in Miles
25
147
9
5
26
19
190
17
22
7
13
18
22
39
15
71
32
16
39
36
58
67
19
25
19
30
14
42
4
27
34
13
34
20
25
3

Figure 1. Sampling locations and associated total beta radioactivity (pCi/liter) in surface waters, April 1968

Table 1. Radioactivity in raw surface waters, April 1968

Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:						
Cedar Hill, N. Mex	3	1	4	9	5	14
Arkansas River:						
Coolidge, Kans	4	34	38	13	54	67
Ponca City, Okla	1	1	2	10	32	42
Atchafalaya River:						
Morgan City, La	9	1	10	28	6	34
Bear River:						
Preston, Idaho	0	1	1	3	19	22
Big Horn River:						
Hardin, Mont	0	4	4	0	22	22
Big Sioux River:						
Sioux Falls, S. Dak	1	3	4	6	12	18
Clearwater River:						
Lewiston, Idaho	0	0	0	1	2	3
Clinch River:						
Clinton, Tenn	0	1	1	2	3	5
Kingston, Tenn [a]	0	<1	<1	1	26	27
Colorado River:						
Loma, Colo	4	1	5	17	22	39
Page, Ariz	<1	7	7	2	17	19
Parker Dam, Calif-Ariz	0	7	7	0	34	34
Columbia River:						
Pasco, Wash [a]	0	1	1	28	119	147
Clatskanie, Ore	0	<1	<1	8	17	25
Connecticut River:						
Enfield Dam, Conn	0	0	0	1	6	7
Coosa River:						
Rome, Ga	<1	0	<1	2	2	4
Cumberland River:						
Cheatham Lock, Tenn	0	0	0	1	3	4
Great Lakes:						
Duluth, Minn	0	0	0	1	8	9
Green River:						
Dutch John, Utah	<1	5	5	<1	15	15
Hudson River:						
Poughkeepsie, N.Y	0	0	0	2	5	7
Illinois River:						
Peoria, Ill	3	2	5	8	8	16
Kansas River:						
DeSoto, Kans	4	1	5	42	26	58
Klamath River:						
Keno, Ore	<1	<1	<1	1	6	7
Mississippi River:						
St. Paul, Minn	1	2	3	3	10	13
E. St. Louis, Ill	2	1	3	10	9	19
New Orleans, La	3	0	3	14	6	20
Missouri River:						
Williston, N. Dak	1	2	3	4	15	19
Bismarck, N. Dak	1	3	4	3	14	17
St. Joseph, Mo	4	1	5	12	24	36
North Platte River:						
Henry, Nebr	2	16	18	10	29	39
Ohio River:						
Cairo, Ill	6	1	7	18	7	25
Pend Oreille River:						
Albeni Falls Dam, Idaho	0	1	1	1	8	9
Platte River:						
Plattsmouth, Nebr	4	5	9	16	16	32
Potomac River:						
Washington, D.C	0	1	1	1	4	5
Red River, North:						
Grand Forks, N. Dak	2	<1	2	10	9	19
Rio Grande:						
Laredo, Tex	4	2	6	15	10	25
San Juan River:						
Shiprock, N. Mex	6	2	8	20	10	30
Savannah River:						
Port Wentworth, Ga [a]	<1	1	1	3	10	13
Snake River:						
Payette, Idaho	1	1	2	<1	9	9
South Platte River:						
Julesburg, Colo	4	36	40	15	56	71
Tennessee River:						
Chattanooga, Tenn	0	1	1	1	7	8
Yellowstone River:						
Sidney, Mont	3	1	4	5	21	26
Maximum	9	36	40	42	119	147
Minimum	0	0	0	0	2	3

[a] Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides.

in terms of changes in radioactivity per unit weight of solids. A discussion of gross radioactivity per gram of solids for all stations of the Water Pollution Surveillance System for 1961 through 1965 has been presented (*7*). Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During April 1968, the following stations showed concentrations in excess of 15 pCi/liter of alpha radioactivity on dissolved solids:

Arkansas River; Coolidge, Kans.
North Platte River; Henry, Nebr.
South Platte River; Julesburg, Colo.

REFERENCES

(*1*) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. National water quality network annual compilation of data, PHS Publication No. 663, 1958 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
(*2*) *Ibid.*, 1959 Edition.
(*3*) *Ibid.*, 1960 Edition.
(*4*) *Ibid.*, 1961 Edition.
(*5*) *Ibid.*, 1962 Edition.
(*6*) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. Water pollution surveillance system, annual compilation of data, PHS Publication No. 663 (Revised), 1963 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
(*7*) JULIAN, E. C. Gross radioactivity of the solids in selected surface wa‘ rs of the United States, 1961–1965. Radiol Heal‘ Data Rep 9:1–15 (January 1968).

Tritium in Surface Water Network, 1967

National Center for Radiological Health
U.S. Public Health Service

A tritium sampling network was established by the Public Health Service in May 1964 to measure and monitor tritium concentrations in major river systems in the United States and to provide surveillance at selected surface water stations downstream from nuclear facilities. The network consists of 10 stations selected from the 131 existing water pollution sampling stations operated by the Federal Water Pollution Control Administration (FWPCA); eight of the stations are located downstream from nuclear facilities and two stations serve to establish baseline levels (figure 1). Reports covering the periods, 1964–1965 (*1*) and 1966 (*2*) have been published previously in *Radiological Health Data and Reports.*

Monthly composites of weekly samples are collected through the FWPCA and sent to the Southeastern Radiological Health Laboratory for analysis. The analyses are carried out using liquid scintillation counting techniques described by Moghissi et al. (*3*). The minimum level of detectability is 0.2 nCi/liter.

Data for the samples collected during 1967 are shown in table 1. Station averages for the year are also presented. The highest concentration observed during 1967 was 16.9 nCi/liter at the Port Wentworth, Ga. station (Savannah River). The highest yearly average, 7.0 nCi/liter, was also observed at the Port Wentworth station. Assuming that the specific activity of tritium in the body is essentially the same as that in the surface water, this average concentration corresponds to an estimated whole-body dose[1] of 1.2 mrem/yr; or in terms of Federal Radiation Council guidance, 0.7 percent of the Radiation Protection Guide (170 mrem/yr) for an average dose to a suitable sample of the exposed population (*4*).

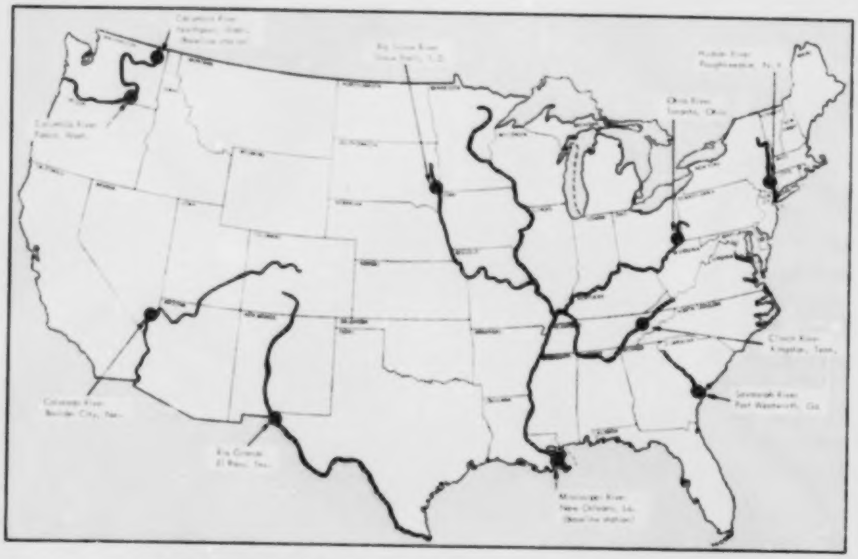
Columbia River
Northport, Wash.
(Baseline station)
Columbia River
Pasco, Wash.
Big Sioux River
Sioux Falls, S.D.
Hudson River
Poughkeepsie, N.Y.
Ohio River
Toronto, Ohio
Clinch River
Kingston, Tenn.
Savannah River
Port Wentworth, Ga.
Colorado River
Boulder City, Nev.
Rio Grande
El Paso, Tex.
Mississippi River
New Orleans, La.
(Baseline station)

Figure 1. Sampling stations for tritium in surface waters

---

[1] Development of the calculations to obtain this dose may be found in reference (*2*).

Table 1. Tritium concentration of surface waters, 1967

Collection site	Concentration [a] (nCi/liter)						
	January	February	March	April	May	June	Average [b]
Big Sioux River, Sioux Falls, S. Dak.	0.7±0.3	2.0±0.3	1.4±0.2	1.1±0.2	1.3±0.2	0.7±0.2	
Clinch River, Kingston, Tenn.	1.3±0.3	5.8±0.3	3.1±0.3	2.9±0.3	10.8±0.5	2.5±0.3	
Colorado River, Boulder City, Nev.	2.4±0.3	2.8±0.3	2.9±0.3	3.0±0.3	2.3±0.3	2.0±0.3	
Columbia River, Northport, Wash. [c]	1.4±0.3	1.8±0.3	1.8±0.3	1.7±0.2	1.8±0.2	1.4±0.2	
Columbia River, Pasco, Wash.	1.6±0.3	1.8±0.3	1.5±0.3	1.7±0.2	1.5±0.2	1.1±0.2	
Hudson River, Poughkeepsie, N.Y.	1.0±0.4	1.2±0.2	1.0±0.3	NS	NS	1.2±0.2	
Mississippi River, New Orleans, La. [c]	[d]0.2±0.2	1.0±0.3	0.8±0.3	1.0±0.2	0.8±0.2	0.7±0.2	
Ohio River, Toronto, Ohio	NS	NS	NS	NS	NS	0.8±0.2	
Rio Grande, El Paso, Tex.	NS	NS	0.9±0.3	NS	0.6±0.2	0.5±0.2	
Savannah River, Port Wentworth, Ga.	6.3±0.4	7.6±0.3	16.9±0.5	9.9±0.3	6.2±0.4	3.7±0.3	
	July	August	September	October	November	December	
Big Sioux River: Sioux Falls, S. Dak.	1.0±0.2	1.0±0.2	0.6±0.2	0.8±0.2	0.6±0.2	<0.2	0.9
Clinch River, Kingston, Tenn.	NS	2.0±0.2	2.2±0.2	2.3±0.3	4.7±0.2	16.0±0.8	4.9
Colorado River, Boulder City, Nev.	2.4±0.3	2.3±0.3	2.3±0.3	2.1±0.3	2.5±0.2	2.4±0.2	2.5
Columbia River, Northport, Wash. [c]	1.0±0.2	1.0±0.2	NS	NS	NS	NS	1.5
Columbia River, Pasco, Wash.	1.4±0.2	0.8±0.2	1.0±0.2	NS	NS	NS	1.4
Hudson River, Poughkeepsie, N.Y.	NS	NS	0.8±0.2	0.8±0.2	1.0±0.2	0.5±0.2	0.9
Mississippi River, New Orleans, La. [c]	0.6±0.2	0.4±0.2	0.6±0.2	0.8±0.2	0.8±0.2	[d]0.2±0.2	0.6
Ohio River, Toronto, Ohio	0.6±0.2	NS	NS	NS	NS	NS	0.7
Rio Grande, El Paso, Tex.	0.5±0.2	0.4±0.2	0.5±0.2	0.4±0.2	<0.2	<0.2	0.4
Savannah River, Port Wentworth, Ga.	4.5±0.2	8.0±0.2	4.7±0.3	4.2±0.3	8.6±0.4	3.6±0.2	7.0

[a] The error reported is the two-sigma error at the 95-percent confidence level.
[b] Values less than or equal to the minimum level of detectability (0.2 nCi/liter) were averaged as zero.
[c] Baseline station.
[d] Values are not statistically significant at the 95-percent confidence level.
NS, no sample.

REFERENCES

(1) CHESNUTT, M. W., J. C. DROBINSKI, JR., and R. H. GORRIE. Tritium in surface waters, 1964–1965. Radiol Health Data Rep 7:377–380 (July 1966).

(2) MOGHISSI, A. A., and C. R. PORTER. Tritium in surface waters of the United States, 1966. Radiol Health Data Rep 9:337–339 (July 1968).

(3) MOGHISSI, A. A., H. L. KELLEY, J. E. REGNIER, and M. W. CARTER. Low level tritium counting by means of liquid scintillation. (To be published.)

(4) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1 (May 13, 1960). Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Radioactivity in Minnesota Municipal Water Supplies[1] July-December 1967

Division of Environmental Sanitation
Minnesota Department of Health

The analysis of various Minnesota waters for radioactivity was initiated in 1956 as part of the Minnesota Water Pollution Control Program. This program was expanded in 1958 to include most of the municipal surface water supplies in the State, as well as selected lakes throughout the State.

As many as 25 surface streams and lakes involving 74 stations have been sampled. At present, nine surface streams and lakes used as municipal water supplies are sampled routinely (figure 1). "Grab" samples of raw and treated water are collected weekly at Hallock, East Grand Forks, Eveleth, Fairmont, and St. Paul and monthly at Crookston, International Falls and St. Cloud. Minneapolis tap water is analyzed weekly. No raw water is collected from the Minneapolis supply.

The samples are forwarded to the Division's laboratory, where they are analyzed for gross alpha and beta radioactivity. A 250-ml sample of water is transferred to a 2-inch planchet and evaporated at 75°C. The solid residue (suspended-plus-dissolved solids) is fixed by adding lucite in acetone. The sample is then counted for alpha or beta radioactivity in an internal-proportional counter. Counter standardization is accomplished by adding known amounts of thallium-204 standard to solutions containing the normal range of solids.

Table 1 shows a summary of the monthly average gross beta radioactivity in Minnesota municipal water supplies from July–December 1967. Table 2 shows the gross alpha radioactivity in the same samples for the same period of time. Alpha radioactivity reported as <1 pCi/liter was considered as 0.5 pCi/liter for averaging purposes.

The data obtained on gross beta radioactivity in Minnesota surface waters show a variation of concentrations, with no readily apparent trends. Variations in precipitation and flow rates of streams could contribute to this fluctuation. Monthly averages of gross beta radioactivity in Minnesota raw surface waters ranged from 6 to 24 pCi/liter, which is well below the Public Health Service Drinking Water Standards (*1*).

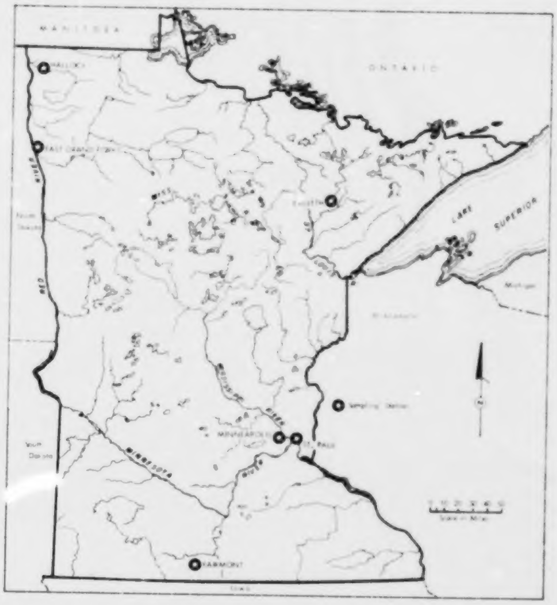

Figure 1. Minnesota surface water sampling locations

---

[1] Data and information from "Survey of Environmental Radioactivity, July–December 1967," Publication No. COO–651–56. State of Minnesota Department of Health, University Campus, Minneapolis, Minn. 55440.

Table 1. Beta radioactivity in Minnesota raw and treated water supplies, July–December 1967

Town and water source	Type of water	Average concentrations (pCi/liter)					
		July	Aug	Sept	Oct	Nov	Dec
Crookston, Red Lake River	Raw	24	15	22	16	20	21
	Treated	16	15	22	16	12	23
East Grand Forks, Red Lake River	Raw	18(4) [a]	16(4)	13(4)	15(5)	13(4)	17(3)
	Treated	11(4)	10(4)	8(4)	8(5)	7(4)	8(3)
Eveleth, St. Mary's Lake	Raw	11(4)	13(5)	10(4)	11(4)	14(5)	11(4)
	Treated	11(4)	14(5)	11(4)	12(4)	12(5)	12(4)
Fairmont, Budd Lake	Raw	11(5)	13(4)	11(4)	13(5)	12(4)	14(3)
	Treated	6(5)	9(4)	8(4)	9(5)	7(4)	9(3)
Hallock, Two Rivers South Fork	Raw	21(4)	19(5)	12(4)	17(2)	21(5)	21(3)
	Treated	8(4)	9(5)	6(4)	6(2)	8(5)	10(3)
International Falls, Rainy River	Raw	11	7	9	7	9	8
	Treated	7	6	9	7	7	7
Minneapolis tap water	Raw						
	Treated	6(5)	5(4)	5(4)	5(5)	3(4)	4(4)
St. Cloud, Mississippi River	Raw	10	9	8	6	9	10
	Treated	7	4	5	9	5	4
St. Paul, Vadnais Chain of Lakes	Raw	11(4)	13(5)	6(4)	10(4)	9(5)	9(4)
	Treated	7(4)	9(5)	6(4)	7(4)	6(5)	6(4)

[a] Number in parentheses gives number of samples averaged.

Table 2. Alpha radioactivity in Minnesota raw and treated water supplies, July–December 1967

Town and water source	Type of water	Average concentrations (pCi/liter)					
		July	Aug	Sept	Oct	Nov	Dec
Crookston, Red Lake River	Raw	1	1	<1	<1	2	2
	Treated	2	<1	<1	<1	<1	<1
East Grand Forks, Red Lake River	Raw	2(4) [a]	<1(4)	2(4)	<1(5)	1(4)	<1(3)
	Treated	<1(4)	<1(4)	1(4)	<1(5)	<1(4)	<1(3)
Eveleth, St. Mary's Lake	Raw	<1(4)	<1(5)	<1(4)	<1(4)	1(5)	<1(4)
	Treated	<1(4)	<1(5)	<1(4)	<1(4)	<1(5)	<1(4)
Fairmont, Budd Lake	Raw	4(5)	4(4)	4(4)	3(5)	3(4)	4(3)
	Treated	<1(5)	<1(4)	<1(4)	<1(5)	<1(4)	1(3)
Hallock, Two Rivers South Fork	Raw	<1(4)	2(5)	<1(4)	2(2)	1(5)	2(3)
	Treated	1(4)	<1(5)	<1(4)	2(2)	<1(5)	1(3)
International Falls, Rainy River	Raw	<1	<1	<1	<1	<1	<1
	Treated	<1	<1	<1	<1	<1	<1
Minneapolis tap water	Raw						
	Treated	1(5)	<1(4)	<1(4)	<1(5)	<1(4)	<1(4)
St. Cloud, Mississippi River	Raw	1	2	<1	<1	<1	<1
	Treated	<1	<1	<1	<1	<1	<1
St. Paul, Vadnais Chain of Lakes	Raw	<1(4)	<1(5)	<1(4)	<1(4)	<1(5)	<1(4)
	Treated	<1(4)	<1(5)	1(4)	<1(4)	<1(5)	<1(4)

[a] Number in parentheses gives number of samples averaged.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1967	January 1968

REFERENCE

(*1*) PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, Public Health Service Publication No. 956, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

Radioactivity in New York Surface Water, June–December 1967

Division of General Engineering and
Radiological Health
State of New York Department of Health

In 1955, the New York State Department of Health began a program to determine the amount of radioactivity in water used for public consumption. Radioactivity in water may arise from any one or a combination of the following sources: the natural mineral content of water (background), atmospheric fallout, or nuclear industry operations. Water samples are obtained from 27 locations for gross beta radioactivity analysis (figure 1). Table 1 gives the sampling frequency and type of sample. Larger samples are collected at selected locations for strontium–90 analysis.

Analytical procedures

Strontium and other alkaline earths are precipitated as carbonates from a 500-ml sample. Iron and rare earths are removed by hydroxide scavenging, while barium is precipitated as a chromate. Strontium is finally precipitated as a sulphate from a pH controlled EDTA solution. Calcium and yttrium remain in solution as EDTA complexes (*1, 2*).

Strontium–90 is determined by yttrium–90 ingrowth counting of the final precipitate at less than 6 hours after precipitation and again at greater than 50 hours using a low background (less than 1 cpm) gas-flow, proportional beta-particle counter. Strontium–89 is estimated by taking the difference between the total strontium and the strontium–90 radioactivity.

Chemical recovery is between 70 and 75 percent and results in a minimum detectable radioactivity of 3 pCi/liter ± 100 percent at the 95-percent confidence level.

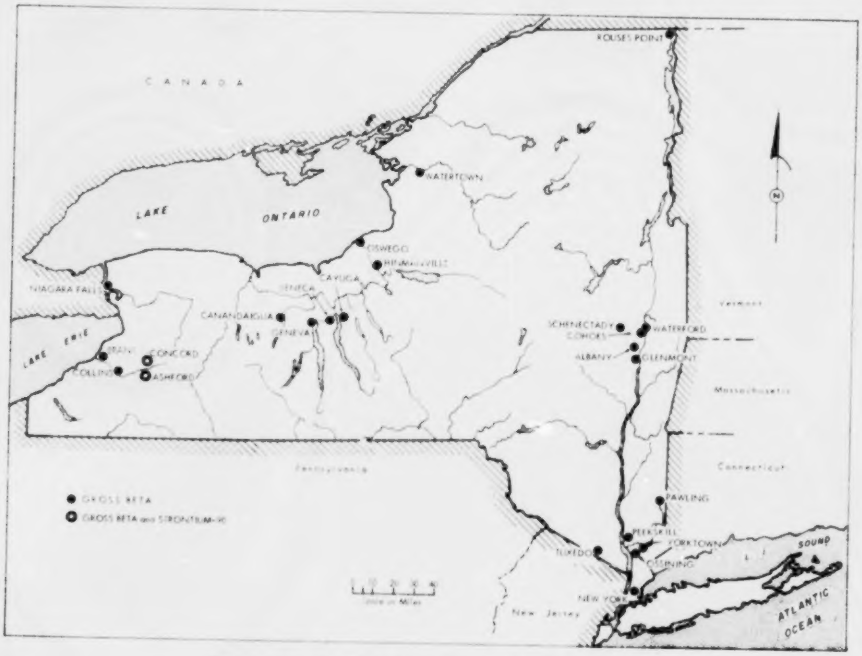
CANADA
LAKE ONTARIO
ROUSES POINT
WATERTOWN
N
OSWEGO
HINMANSVILLE
CAYUGA
SENECA
NIAGARA FALLS
CANANDAIGUA
GENEVA
LAKE ERIE
IRVING
CONCORD
COLLINS
ASHFORD
SCHENECTADY
COHOES
WATERFORD
ALBANY
GLENMONT
Vermont
Massachusetts
Connecticut
Pennsylvania
GROSS BETA
GROSS BETA and STRONTIUM-90
PAWLING
PEEKSKILL
YORKTOWN
TUXEDO
OSSINING
SOUND
NEW YORK
New Jersey
0 10 20 30 40
Scale in Miles
ATLANTIC OCEAN

Figure 1. New York water sampling locations

Table 1. Gross beta radioactivity in New York raw surface water, June- December 1967

Location	Sampling [a]	Gross beta radioactivity (pCi/liter)						
		June	July	Aug	Sept	Oct	Nov	Dec
Albany	BW	5	3	NS	NS	NS	NS	2
Ashford (Buttermilk Creek at Thomas Corners)	W	1,052(3) [b]	1,782(3)	561(4)	1,819(5)	1,129(4)	499(2)	NS
Brant (Cattaraugus Creek)	W	24(2)	79(4)	39(5)	41(4)	58(4)	54(5)	20
Cohoes (Mohawk River)	D	NS	NS	NS	3(3)	3(4)	3(4)	3(2)
Collins (Cattaraugus Creek)	M	41(2)	66(4)	42(5)	64(4)	51(4)	46(5)	89
Concord (Cattaraugus Creek)	D	87(11)	118(17)	82(22)	115(13)	110(18)	124(18)	153(19)
Geneva (Seneca Lake)	SA	NS	NS	NS	NS	3	NS	NS
Glenmont (Hudson River)	D	NS	4	4	3(3)	3(3)	2(4)	3(4)
Lansing	SA	NS	NS	1(5)	NS	NS	NS	NS
New York City	SA	NS	NS	NS	NS	3(2)	3	NS
Niagara Falls (East Branch-Niagara River)	Q	NS	4	4	NS	NS	NS	NS
(West Branch-Niagara River)	Q	NS	4	NS	4	5	1	0
Ossining (Hudson River)	D	26(4)	24(4)	19(5)	40(3)	37(5)	8(4)	7
(Indian Brook Reservoir)	M	NS	24(2)	4	4	3	5	NS
Oswego (Lake Ontario)	M	NS	NS	4	NS	3	NS	NS
Pawling (Pond at United Nuclear)	M	NS	NS	4	3(2)	NS	3	2
Peekskill (Camp Field water supply)	M	NS	NS	3	8	1	1	4
(Hudson River)	D	8(3)	10(4)	10(4)	18(4)	20(5)	5(4)	4(4)
Schenectady (Mohawk River)	C	NS	3(3)	4(4)	3(5)	3(5)	1(3)	3
Tuxedo (Indian Hill)	M	NS	NS	5	3	4	3	0
Watertown (Black River)	BW	5	NS	3	3	3(3)	4(2)	2(2)
Yorktown (Croton Reservoir)	M	NS	NS	5	3	NS	4	NS

[a] BW, Biweekly composite of daily grab samples.
W, weekly sample.
D, weekly composite of daily grab samples.
C, continuous bleed-off analyzed weekly.
M, monthly grab sample.
Q, quarterly grab sample.
SA, semiannual grab sample.

[b] Figures in parentheses are number of samples in average.

NS, no sample.

Discussion and results

The observed gross beta-particle concentrations in New York surface water for June–December 1967 are given in table 1. The Ashford station at Thomas Corners, Brant, Collins and Concord stations are located downstream from the Nuclear Fuels Services reprocessing plant and show concentration levels well above natural background. The higher gross beta radioactivity levels in water at the Peekskill and Ossining stations reflect the intrusion of saline water at those points.

The average concentrations of strontium–89 and strontium–90 in New York water for June through December 1967 for the Ashford and Concord stations are given in table 2.

Table 2. Strontium–90 in New York surface waters [a] June-December 1967

Location	Month (1967)	Strontium-90 (pCi/liter)
Ashford (Cattaraugus Creek at Bigelow Bridge)	June	<3
	July	<3
	August	8
	September	<3
	October	<3
	November	<3
	December	NA
Concord [b] (Springville Power Dam on Cattaraugus Creek)	August	15
	September	26
	October	<3
	November	NA
	December	NA

[a] No analysis was done for strontium-89 for these periods.

[b] These samples were collected from a sampling station located downstream from the Nuclear Fuel Services spent fuel processing plant located in Cattaraugus County.

NA, no analysis.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January–December 1966	September 1967
January–May 1967	January 1968

REFERENCES

(1) PORTER, C., D. CAHILL, R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Improved determination of strontium–90 in milk by ion-exchange method. Anal Chem 33:1306–1308 (September 1961).

(2) WELFORD, G., and D. SUTTON, a paper presented at the American Chemical Society meeting in New York City, September 1960.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta-radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports:*

Network	Period	Issue
80th Meridian Network, HASL	July–December 1967	September 1968
Fallout Network, HASL	Calendar Year 1965	January 1967

1. Radiation Alert Network
June 1968

National Center for Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on airborne particulate samples at 5 hours after collection when most of the radon daughter products have decayed and at 29 hours after collection when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate National Center for Radiological Health officials by mail or telephone, depending on levels found. Compilation of the daily field estimates is reported elsewhere on a monthly basis (*1*). A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during June 1968. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.

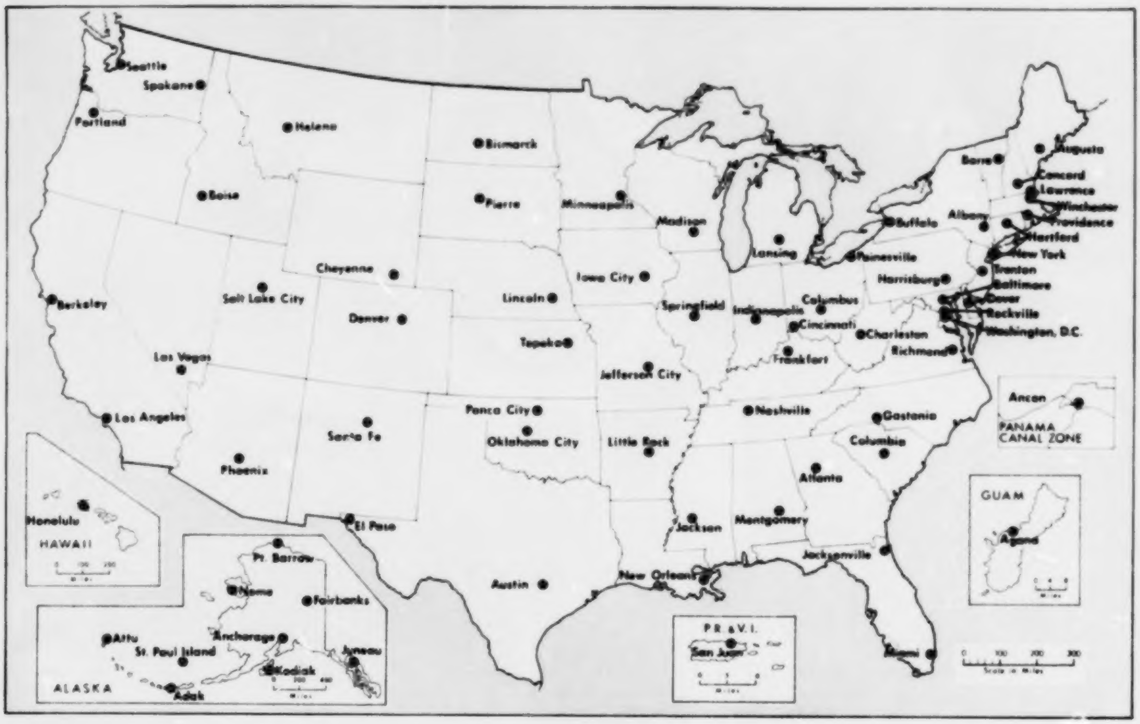
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Madison
Lansing
Buffalo
Barre
Augusta
Concord
Lawrence
Winchester
Providence
Albany
Hartford
New York
Painesville
Trenton
Harrisburg
Baltimore
Dover
Rockville
Washington, D.C.
Cheyenne
Iowa City
Salt Lake City
Berkeley
Lincoln
Denver
Springfield
Indianapolis
Columbus
Cincinnati
Charleston
Topeka
Richmond
Frankfort
Las Vegas
Jefferson City
Ancon
PANAMA CANAL ZONE
Los Angeles
Ponca City
Nashville
Gastonia
Santa Fe
Oklahoma City
Little Rock
Columbia
Phoenix
Atlanta
GUAM
Agana
Honolulu
HAWAII
El Paso
Jackson
Montgomery
Pt. Barrow
Jacksonville
Nome
Fairbanks
Austin
New Orleans
Attu
Anchorage
St. Paul Island
Juneau
Kodiak
ALASKA
Adak
P.R. & V.I.
San Juan
Miami
0 100 200 300
Scale in Miles

Figure 1. Radiation Alert Network sampling stations

49

Table 1. Gross beta radioactivity in surface air and precipitation, June 1968

Station location		Number of samples		Air surveillance gross beta radioactivity (pCi/m³)			Last profile in RHD&R	Precipitation			
								Total depth (mm)	Field estimation of deposition		
		Air	Pptn	Maximum	Minimum	Average [a]			Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	20	1	4.61	1.05	2.23	Sept 68	40	1	40	45
Alaska:	Adak	30		1.43	.36	.91	Apr 68	(c)			
	Anchorage	27		.00	.00	.00	Oct 68	(c)			
	Attu Island	(b)					May 68	(c)			
	Fairbanks	27	12	.75	.00	.20	Jan 68	38	12	38	10
	Juneau	28	9	.00	.00	.00	Feb 68	55	9	55	0
	Kodiak	26		1.87	.16	.60	Mar 68	(c)			
	Nome	(b)					July 68	(c)			
	Point Barrow	25		1.49	1.14	1.23	June 68	(c)			
	St. Paul Island	29		.93	.43	.45	Aug 68	(c)			
Ariz:	Phoenix	19		21.24	1.61	6.15	Feb 68	(c)			
Ark:	Little Rock	9	2	2.02	.25	1.26	Oct 68	115	2	115	0
Calif:	Berkeley	19		.82	.00	.24	Mar 68	(c)			
	Los Angeles	19		1.72	.27	.68	July 68	(c)			
C. Z:	Ancon	11		3.01	1.29	2.11	Mar 68	(c)			
Colo:	Denver	20		5.32	1.23	2.86	Mar 68	86	(d)		
Conn:	Hartford	20	12	.52	.23	.30	Jan 68	139	12	139	0
Del:	Dover	20		1.06	.17	.53	Sept 68	(c)			
D. C:	Washington	20	9	2.04	.30	.99	June 68	114	9	114	9
Fla:	Jacksonville	20	4	1.05	.00	.51	Oct 68	77	0	0	(e)
	Miami	16	7	.24	.08	.18	Jan 68	233	7	233	0
Ga:	Atlanta	18		1.24	.78	1.01	Aug 68	(c)			
Guam:	Agana	19		.67	.22	.49	Sept 68	(c)			
Hawaii:	Honolulu	30		.66	.31	.61	May 68	91	(d)		
Idaho:	Boise	20	3	12.89	.38	1.60	May 68	19	3	19	0
Ill:	Springfield	18		5.50	.55	2.50	June 68	(c)			
Ind:	Indianapolis	20	3	2.92	.60	1.57	Aug 68	43	3	43	111
Iowa:	Iowa City	19		4.31	.65	1.50	Mar 68	(c)			
Kans:	Topeka	20	5	4.76	.61	1.92	Oct 68	85	5	85	0
Ky:	Frankfort	12	3	4.29	.36	1.26	June 68	22	3	22	10
La:	New Orleans	20		1.01	.24	.53	June 68	(c)			
Maine:	Augusta	21	14	.79	.18	.37	July 68	145	14	145	0
Md:	Baltimore	20	5	2.94	.35	.96	Jan 68	4	5	4	0
	Rockville	16	1	1.06	.34	.61	May 68	106	(d)		
Mass:	Lawrence	11	10	.85	.00	.49	Sept 68	147	0	0	(e)
	Winchester	20	14	1.60	.00	.34	Apr 68	134	14	134	0
Mich:	Lansing	20	11	4.56	.58	1.87	May 68	144	11	144	1.278
Minn:	Minneapolis	19	11	1.20	.07	.27	Sept 68	154	11	154	
Miss:	Jackson	18	3	2.29	.22	.76	July 68	49	3	49	
Mo:	Jefferson City	20	5	3.55	.54	1.42	Aug 68	70	5	70	
Mont:	Helena	16	7	2.64	.36	.93	Apr 68	50	7	50	
Nebr:	Lincoln	19		3.89	.30	1.60	Aug 68	(c)			
Nev:	Las Vegas	18		2.94	.47	1.55	Jan 68	(c)			
N. H:	Concord	20		1.62	.44	.76	June 68	(c)			
N. J:	Trenton	19	6	2.54	.39	.74	July 68	138	6	138	
N. Mex:	Sante Fe	17		19.60	.24	1.52	Apr 68	(c)			
N. Y:	Buffalo	(b)					Aug 68	(c)			
	New York City	17		1.47	.31	.73	Mar 68	(c)			
N. C:	Gastonia	18		.39	.16	.25	Apr 68	(c)			
N. Dak:	Bismarck	16		8.71	1.41	3.37	Mar 68	45	(d)		
Ohio:	Cincinnati	19		2.17	.27	.88	June 68	(c)			
	Columbus	(b)					Sept 68	(c)			
	Painesville	17	4	2.46	.35	1.05	July 68	86	2	37	0
Okla:	Oklahoma City	20	6	1.45	.00	.61	Jan 68	54	6	54	0
	Ponca City	17	2	4.03	.00	1.64	May 68	44	2	44	182
Ore:	Portland	19	4	2.10	.08	.57	Jan 68	50	4	50	0
Pa:	Harrisburg	20	5	1.50	.21	.40	Aug 68	31	5	31	0
P. R:	San Juan	15	1	2.48	.37	.83	Aug 68	25	0	0	(e)
R. I:	Providence	(b)					July 68	(c)			
S. C:	Columbia	9		.31	.15	.26	May 68	(c)			
S. Dak:	Pierre	17		.95	.20	.42	Apr 68	(c)			
Tenn:	Nashville	4		1.55	.73	1.02	Feb 68	(c)			
Tex:	Austin	17	1	2.27	.42	1.19	May 68	12	1	1	0
	El Paso	15		5.64	.38	1.88	Sept 68	77	(d)		
Utah:	Salt Lake City	20		5.23	.96	2.09	June 68	(c)			
Vt:	Barre	29	2	2.19	.51	1.22	July 68	12	0	0	(e)
Va:	Richmond	20	12	1.89	.21	.86	Oct 68	92	12	92	4
Wash:	Seattle	12	1	.74	.18	.50	Oct 68	19	0	0	(e)
	Spokane	22		.00	.00	.00	Oct 68	71	(d)		
W. Va:	Charleston	20	4	2.87	.63	1.50	Sept 68	7	0	0	(e)
Wisc:	Madison	19	7	2.19	.24	.85	Apr 68	47	7	47	24
Wyo:	Cheyenne	20	9	2.08	.00	.82	Oct 68	190	9	190	180
		20	2	5.61	.91	2.83	Jan 68	19	2	19	20
Network summary		1.257	217	21.24	0.00	1.10		75	6	79	76

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] No report received (air samples submitted without field estimate data are not considered by the data program).
[c] No precipitation sample collected.
[d] This station is part of the plutonium in precipitation network. Gross beta analysis is not done.
[e] Samples were collected but no field estimates were reported.

50

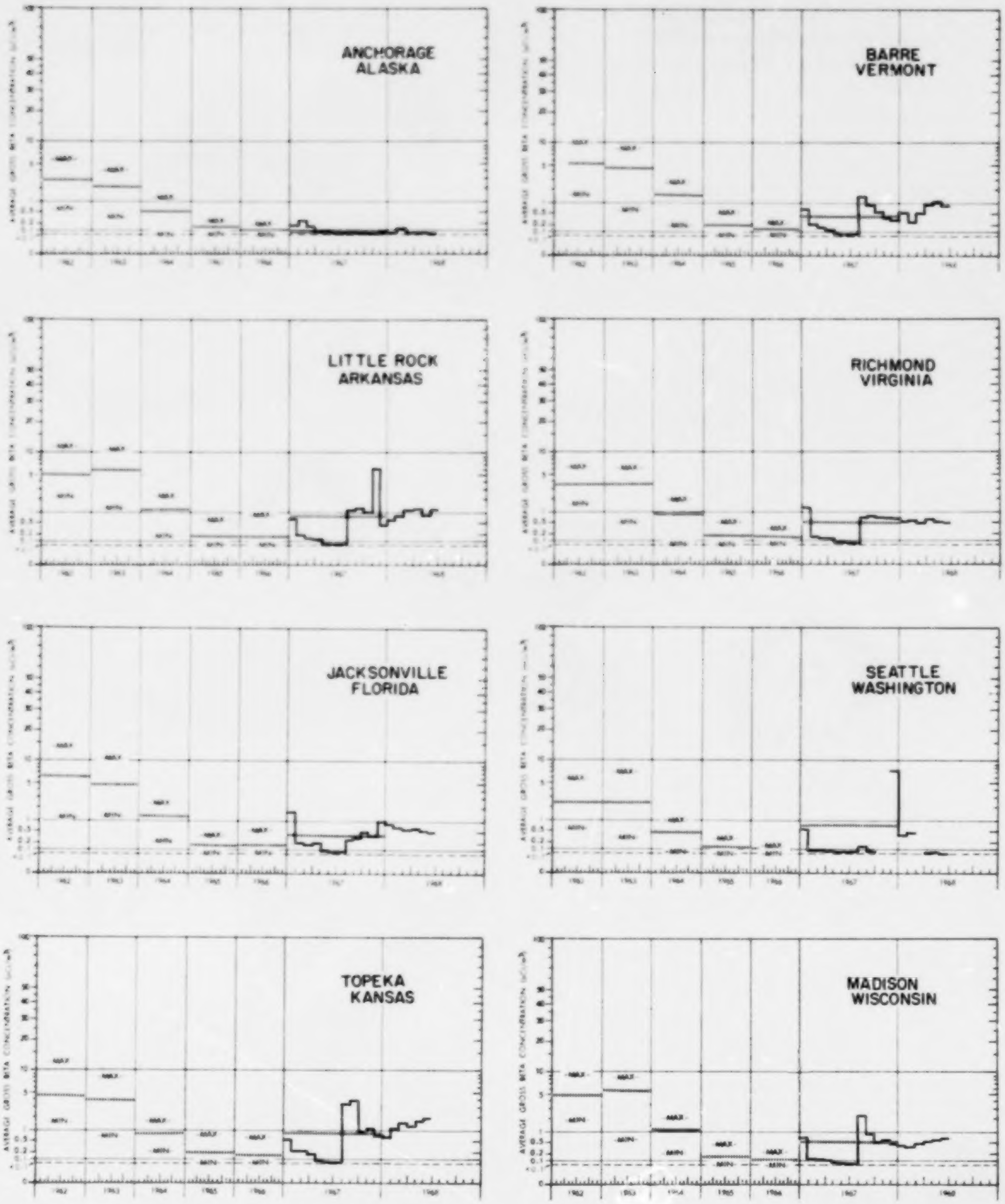

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1962–June 1968

51

2. Canadian Air and Precipitation Monitoring Program[1], June 1968

Radiation Protection Division

Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*2–6*).

A summary of the sampling procedures and methods of analysis was presented in the April 1968 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for June 1968 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, June 1968

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi m²)
Calgary	30	0.5	0.0	0.2	97	5.3
Coral Harbour	28	.2	.0	.1	51	2.5
Edmonton	30	.3	.0	.2	129	8.8
Ft. Churchill	29	.4	.0	.1	96	3.0
Ft. William	30	.3	.0	.1	81	9.9
Fredericton	29	.4	.0	.1	65	5.6
Goose Bay	30	.3	.0	.1	95	5.8
Halifax	29	.2	.0	.0	48	6.6
Inuvik	30	.2	.0	.1	497	1.1
Montreal	30	.4	.0	.2	113	9.7
Moosonee	29	.4	.0	.2	32	2.9
Ottawa	30	.4	.0	.2	81	8.6
Quebec	29	.3	.0	.1	93	6.1
Regina	39	.4	.0	.2	208	2.9
Resolute	24	.1	.0	.0	20	0.3
St. John's, Nfld	30	.2	.0	.1	44	6.8
Saskatoon	30	.3	.0	.2	144	5.4
Sault Ste Marie	25	.5	.0	.2	116	11.1
Toronto	29	.4	.0	.2	87	6.5
Vancouver	30	.3	.0	.1	72	4.9
Whitehorse	30	.2	.0	.1	NS	NS
Windsor	29	.3	.0	.2	45	6.8
Winnipeg	30	.3	.0	.2	115	9.5
Yellowknife	30	.4	.0	.2	160	2.2
Network summary	29	0.3	0.0	0.1	108	5.8

NS, no sample.

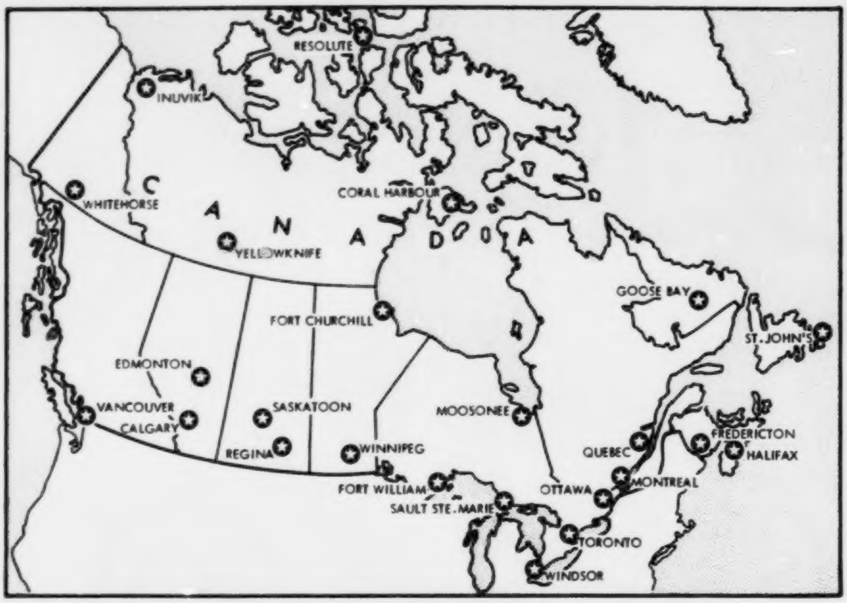
RESOLUTE
INUVIK
WHITEHORSE
C
A
N
A
D
A
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
FORT CHURCHILL
ST. JOHN'S
EDMONTON
VANCOUVER
CALGARY
SASKATOON
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
FORT WILLIAM
OTTAWA
MONTREAL
SAULT STE. MARIE
TORONTO
WINDSOR

Figure 3. Canadian air and precipitation sampling stations

---

[1] Prepared from information and data in the July 1968 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

3. Mexican Air Monitoring Program
June 1968

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNE.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirrección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Prevision de Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Desrérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6- by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high-volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron daughters. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of five samples per month were needed to get a reliable average radioactivity at each station (7).

The maximum, minimum, and average beta radioactivity in surface air during June 1968 are presented in table 3.

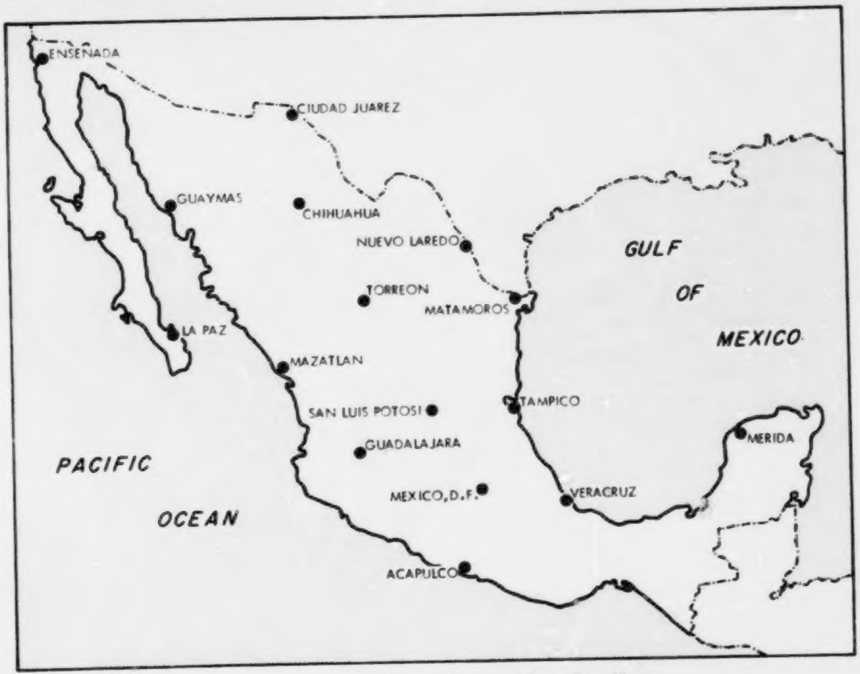

Figure 4. Mexican air sampling locations

Table 3. Mexican gross beta radioactivity of airborne particulates, June 1968

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average [a]
Acapulco	NS	NS	NS	NS
Chihuahua	2	0.4	0.3	—
Ciudad Juarez	5	.5	.2	0.4
Ensenada	NS	NS	NS	NS
Guadalajara	NS	NS	NS	NS
Guaymas	NS	NS	NS	NS
La Paz	15	.5	.1	.4
Matamoros	NS	NS	NS	NS
Mazatlán	7	1.2	0.2	.5
Mérida	15	.4	.1	.2
México, D. F	1	.1	.1	—
Nuevo Laredo	3	.1	.1	.1
San Luis Potosí	NS	NS	NS	NS
Tampico	12	.5	<.1	.1
Terreón	11	.3	.1	.2
Veracruz	2	.1	.1	—

NS, station temporarily shut down, no sample.

4. Pan American Air Sampling Program June 1968

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling locations are shown in figure 5. Analytical techniques were described in the March 1968 *Radiological Health Data and Reports*. The June 1968 air monitoring results from the participating countries are given in table 4.

Table 4. Summary of gross beta radioactivity in Pan American surface air, June 1968

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average [a]
Argentina:	Buenos Aires	12	0.06	0.01	0.02
Bolivia:	La Paz	16	.04	.01	.03
Chile:	Santiago	30	.38	.01	.04
Colombia:	Bogota	18	.01	.00	.01
Ecuador:	Guayaquil	18	.03	.02	.02
Jamaica:	Kingston	19	.14	.02	.08
Peru:	Lima	13	.04	.01	.03
Venezuela:	Caracas	16	.61	.02	.13
West Indies:	Trinidad	17	.12	.01	.07
Pan American summary		159	0.61	0.00	0.05

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

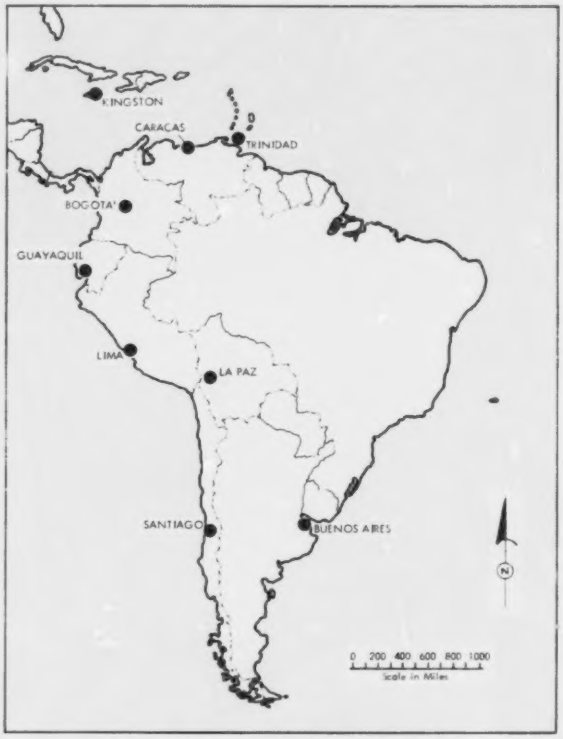

Figure 5. Pan American Air Sampling Program stations

REFERENCES

(*1*) PUBLIC HEALTH SERVICE. Environmental Radiation Surveillance Report. National Center for Radiological Health, Standards and Intelligence Branch, Rockville, Md. 20852 (Distribution by official request).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*3*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW-RP-4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*4*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*5*) BEALE, J., and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*6*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

(*7*) VASQUEZ, M., and R. M. DE NULMAN. Estudios sobre la radioactividad ambiental en la República Mexicana, 1963-1965. Comisión Nacional de Energía Nuclear, Dirección General de Seguridad Radiológica (1966).

55

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity in Mexico, January–June 1967

Comisión Nacional de Energía Nuclear

The Dirección General de Seguridad Radiológica of the Comisión Nacional de Energía Nuclear (CNEN) in Mexico through its Environmental Activity Section operates surveillance networks monitoring airborne particulates, rainwater, drinking water, milk, food and sea water.

Samples are collected at sampling stations located throughout the Mexican Republic with emphasis given to the Nuclear Center site and its surroundings (Nuclear Center is still under construction). Sampling, analytical and counting techniques have been described (*1*). The location of sampling stations in the Mexican Republic is shown in figure 1. The tables present radioactivity levels for the first half of 1967.

Radioactivity of particulates in air is summarized in tables 1 and 2. Gross beta radioactivity of airborne particulates is given for 17 stations in table 1. Results of a special study on radiochemical separations of particulates in air for strontium-90, cesium-137 and potassium-40 are shown in table 2 at four locations.

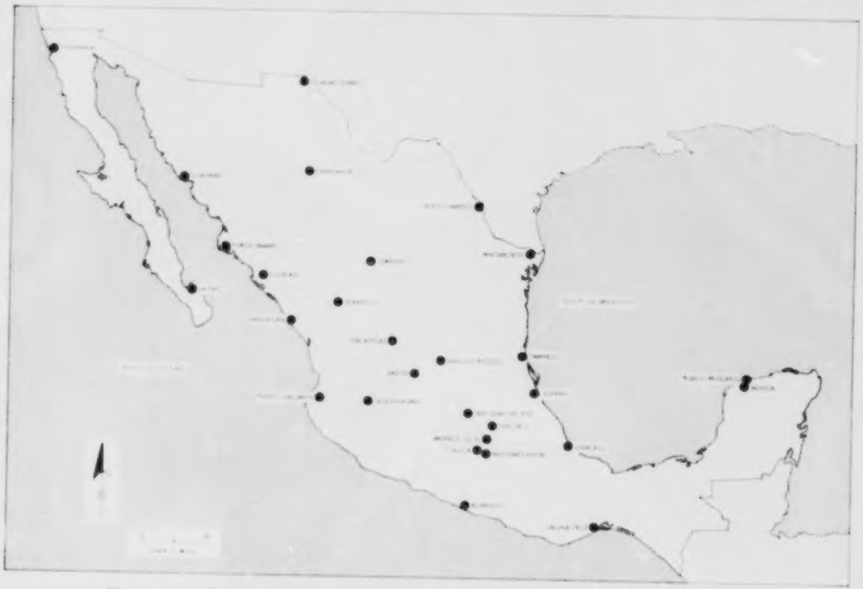

Figure 1. Location of sampling stations in the Mexican Republic

Table 1. Gross beta radioactivity of airborne particulates, Mexico, January–June 1967

Station	Average gross beta radioactivity concentration (pCi/m³)					
	Jan	Feb	Mar	Apr	May	June
Acapulco	0.1	0.2	0.3	0.3	0.1	0.1
Chihuahua	.2	.2	.3	.2	.1	.1
Ciudad Juárez	3.2	.3	.3	.2	.1	<.1
Ensenada	.2	.3	.3	.1	.1	.1
Guadalajara	.1	NS	.1	.1	NS	.1
Guaymas	.3	NS	NS	NS	NS	NS
La Paz	.1	.6	.4	.2	.1	.1
Matamoros	NS	NS	NS	NS	NS	NS
Mazatlán	.1	.3	.5	.2	.1	.1
Mérida	.3	.2	.1	.1	.1	.1
México, D. F.	.1	.1	.1	.1	.1	.1
Nuevo Laredo	.1	.1	.2	.1	.1	NS
San Luis Potosí	<.1	NS	NS	NS	NS	NS
Tampico	.1	NS	.1	.1	.1	NS
Torreón	.2	.2	.3	.1	.1	<.1
Veracruz	.1	.1	NS	.1	.1	.1
Nuclear Center	.1	NS	NS	NS	<.1	.1

NS, no sample.

Table 2. Radiochemical analysis of particulates in composite air samples, Mexico, January–June 1967

Station	Date	Potassium-40 (pCi/10,000 m³)	Strontium-90 (pCi/10,000 m³)	Cesium-137 (pCi/10,000 m³)
Chihuahua	Jan–Feb	33.9	3.4±0.1	3.4±0.1
	Mar–Apr	9.7	3.7±0.1	20.7±4.0
	May–June	9.3	3.4±1.2	8.3±2.0
Cuidad Juárez	Jan–Feb	4.9	3.0±0.1	21.0±0.1
Mérida	Jan–Feb	21.0	4.0±0.1	15.0±0.1
	Mar–Apr	8.3	3.2±0.6	20.8±4.0
	May–June	9.1	9.0±1.3	20.2±4.0
México, D. F.	Jan–Feb	36.0	2.8±0.1	7.8±0.5
	Mar–Apr	10.3	2.9±0.2	14.4±3.0
	May–June	8.6	3.0±0.5	7.9±2.0

Except for a special study, radiochemical separations are made only on samples containing daily concentrations greater than 1 pCi/m³.

Table 3 shows the beta radioactivity in rainwater at five locations. Table 4 shows gross beta radioactivity in Mexico City drinking water and drinking river and lake water in various locations near the Nuclear Center. Drinking water is sampled weekly in Mexico City and monthly from areas around the Nuclear Center.

Strontium–90 concentrations in liquid milk samples collected at ten locations and powdered milk samples collected at two locations are given in table 5. Milk samples are collected from different locations in Mexico with several sampling locations near Mexico City and the Nuclear Center. Gross beta radioactivity and strontium–90 values in foods are given in tables 6 and 7.

Table 6 shows gross beta radioactivity values in foods collected primarily from the Mexico

Table 3. Gross beta radioactivity in rainwater, Mexico, January–June 1967

Station	Concentrations and deposition of gross beta radioactivity	Sample fraction [a]	1967					
			Jan	Feb	Mar	April	May	June
Chihuahua	pCi/liter	SS	4.9	0.6		1.5	12.7	3.0
		DS	3.6	6.7		19.3	8.9	3.0
	nCi/m²	SS	.1	.2		.1	.3	.1
		DS	.1	.3		1.2	.1	.1
Mérida	pCi/liter	SS			31.3	3.0	3.0	4.0
		DS			33.7	3.0	3.0	3.0
	nCi/m²	SS			4.2	.3	.3	.3
		DS			4.5	.4	.2	.1
México, D. F.	pCi/liter	SS	3.0	38.0	36.8	8.7	15.8	3.0
		DS	4.0	28.1	5.6	3.0	3.0	3.0
	nCi/m²	SS	.4	.3	.2	.3	2.2	.4
		DS	.6	.2	.3	.3	.1	.3
Torreón	pCi/liter	SS	15.0	18.4	10.2			
		DS	10.5	13.9	3.4			
	nCi/m²	SS	.2	.2	.4			
		DS	.1	.2	.1			
Nuclear Center	pCi/liter	SS			19.4	3.0	4.3	3.0
		DS			12.1	5.8	3.0	3.0
	nCi/m²	SS			2.3	.4	.1	.1
		DS			1.4	.8	.1	.2

[a] SS, suspended solids.
DS, dissolved solids.

Table 4. Gross beta radioactivity in Mexico City drinking water and in lake, river, and drinking water near the Nuclear Center

Station	Sample fraction [a]	Average concentrations (pCi/liter)					
		1967					
		January	February	March	April	May	June
México, D. F	SS		<3	<3	<3	<3	<3
	DS		4.2	<3	2.7	2.7	1.3
Colonial Ortiz Rubio	SS		<3	<3	<3	<3	<3
	DS		2.5	<3	<3	1.6	3
Cuajimlapa	SS			<3	<3	<3	<3
	DS			<3	<3	<3	<3
Huixquilucan	SS		<3	<3	<3	<3	<3
	DS		2.6	<3	<3	<3	<3
Laguana Salazar	SS			<3	<3	<3	<3
	DS			1.2	<3	<3	<3
Lerma De Villada	SS	<3	9.9	<3	<3	<3	<3
	DS	<3	11.0	<3	<3	6.0	11.8
Ocoyoacac	SS		<3	<3	3.4	1.8	<3
	DS		<3	<3	<3	1.2	<3
San Ignacio Allende	SS		9.9	<3	5.1	<3	<3
	DS		11.0	<3	<3	2.0	<3
San Mateo Ataraaquillo	SS	<3		<3	<3	<3	<3
	DS	<3		5.6	<3	1.4	<3
San Miquel Ameyalco	SS	<3		1.4	<3	<3	<3
	DS	3.2		1.9	<3	<3	<3
San Pedro Atlapulco drinking water	SS			<3	<3	<3	<3
	DS			5.7	<3	1.6	<3
river water	SS			<3	1.4		<3
	DS			5.7	<3		<3

[a] SS, suspended solids.
DS, dissolved solids.

City area and around the Nuclear Center during the first half of 1967. Table 7 gives radioactivity values for some foods that have been harvested prior to 1967. The most elevated beta radioactivity values were detected in horsebeans.

Radiochemical analyses of beta radioactivity in sea water samples taken near sites of six ports are shown in table 8. Samples are taken 5 kilometers from shore near ports of the Pacific Ocean and the Gulf of Mexico. If sea water samples contain gross beta radioactivity greater than one-tenth of the maximum permissible concentration for drinking water, they are analyzed for strontium-90 and cesium-137.

Table 5. Strontium-90 in milk, Mexico, January-June 1967

Station	Strontium-90 concentration of monthly composite	January	February	March	April	May	June
Chalco	pCi/liter	<1	<1	<1	<1	1.4 ± 0.6	<1
	pCi/g Ca	<1	<1	<1	<1	1.0 ± 0.4	<1
Chihuahua	pCi/liter	1.4 ± 0.5	<1	<1	<1	15.5 ± 1.4	8.8 ± 0.7
	pCi/g Ca	1.5 ± 0.5	<1	<1	<1	9.1 ± 0.8	5.5 ± 0.4
Coapa	pCi/liter	<1	<1	<1	<1	<1	<1
	pCi/g Ca	<1	<1	<1	<1	<1	<1
Huixilucan	pCi/liter	3.9 ± 0.7	<1	<1	<1	<1	2.8 ± 0.2
	pCi/g Ca	2.6 ± 0.4	<1	<1	<1	<1	2.0 ± 0.1
Mérida	pCi/liter			<1	1.0 ± 0.5		<1
	pCi/g Ca			<1	0.7 ± 0.4		<1
San Juan Del Río	pCi/liter						<1
	pCi/g Ca						<1
San Mateo Atarasquiello	pCi/liter					1.2 ± 0.7	2.3 ± 0.4
	pCi/g Ca					0.6 ± 0.4	1.8 ± 0.3
Texcoco	pCi/liter	<1	<1	<1	<1	<1	<1
	pCi/g Ca	<1	<1	<1	<1	<1	<1
Toluca	pCi/liter	1.2 ± 0.4	3.6 ± 0.5	1	1	9.2 ± 1.2	2.4 ± 1.5
	pCi/g Ca	1.0 ± 0.3	2.8 ± 0.4	1	1	6.1 ± 0.8	2.3 ± 1.4
Veracruz	pCi/liter	1.5 ± 1.0	1.4 ± 0.2	<1	1.4 ± 0.4	<1	<1
	pCi/g Ca	1.3 ± 0.7	1.1 ± 0.16	<1	0.8 ± 0.2	<1	<1
Lagos [a]	pCi/liter	<1	<1	<1	<1	1.1 ± 0.7	2.0 ± 0.7
	pCi/g Ca	<1	<1	<1	<1		1.6 ± 0.6
Tamuin [a]	pCi/liter			<1	<1		
	pCi/g Ca			<1	<		

[a] Powdered milk sampling station.

58

Table 6. Gross beta radioactivity in foods, Mexico

Food	Sampling location	Date of collection	Gross radioactivity (pCi/kg) dry base
Beans	Huixquilucan	3/29/67	1,776
Horsebeans	Huixquilucan	3/29/67	14,435
	San Ignacio Allende	3/29/67	14,741
Corn	Huixquilucan	3/29/67	4,858
Pulque	Huixquilucan	2/22/67	345
	San Ignacio Allende	1/5/67	295
		2/22/67	116
		3/30/67	598
		4/26/67	588
		5/26/67	1,500
		6/28/67	614
	San Jeronimo Acazulco	1/18/67	853
		4/11/67	932
		6/14/67	875
	San Mateo Atarasquillo	1/25/67	231
		3/15/67	1,131
		4/19/67	668
		5/23/67	1,142
		6/21/67	725
	San Pedro Atlapulco	3/8/67	1,693
		5/17/67	940

Table 7. Gross beta radioactivity and strontium-90 in foods, Mexico, 1961–1967

Food and station	Harvest date	Gross beta radioactivity (pCi/kg) dry base	Strontium-90 (pCi/kg) dry base
Beans:			
Ganajuato	61/62	6,820	<1
Zacatecas	62/63	3,870	12.5±7.2
	64/65	3,920	<1
Chihuahua	64/65	10,050	4.5±1.3
Durango	66/67	9,400	15.4±1.5
Corn:			
Durango	64/65	4,925	<1
San Luis Potosí	66/67	4,654	<1
Fish:			
Mazatlán and Topolobampo	4/28/67	1,275	<1

Table 8. Radiochemical analysis of sea water, Mexico, January-June 1967

Station	Date (1967)	Suspended solids (pCi/liter)	Beta radioactivity in insoluble sulfides (pCi/liter)	Beta radioactivity in insoluble carbonates (pCi/liter)	Beta radioactivity in soluble carbonates (pCi/liter)
Ensenada	February	0.22±0.02	6.55±0.17	2.00±0.34	80± 6
Mazatlán	February	.16± .02	1.80± .18	3.08± .65	179± 6
Salina Cruz	February	.1	.13± .01	6.66± .01	198±15
Puerto Progresso	June	.1	4.54± .28	3.48± .28	32±18
Puerto Vallarta	June	.14± .03	3.96± .05	4.09± .65	386±39
Veracruz	June	.1	1.99± .9	2.51± .6	283±12

REFERENCE

(1) NULMAN, R. M. and M. VASQUEZ BARETE. Radioactivity in the Mexican environment. Radiol Health Data Rep 9:495-501 (September 1967).

59

Strontium–90 in Human Bone,[1] July–September 1967

National Center for Radiological Health
Public Health Service

To obtain data on the concentration of strontium–90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. Analyses of selected samples of people in older age groups have shown their bone strontium–90 content to be low and age-independent (*1*). Consequently, the target population includes children and young adults up to 25 years of age.

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age.

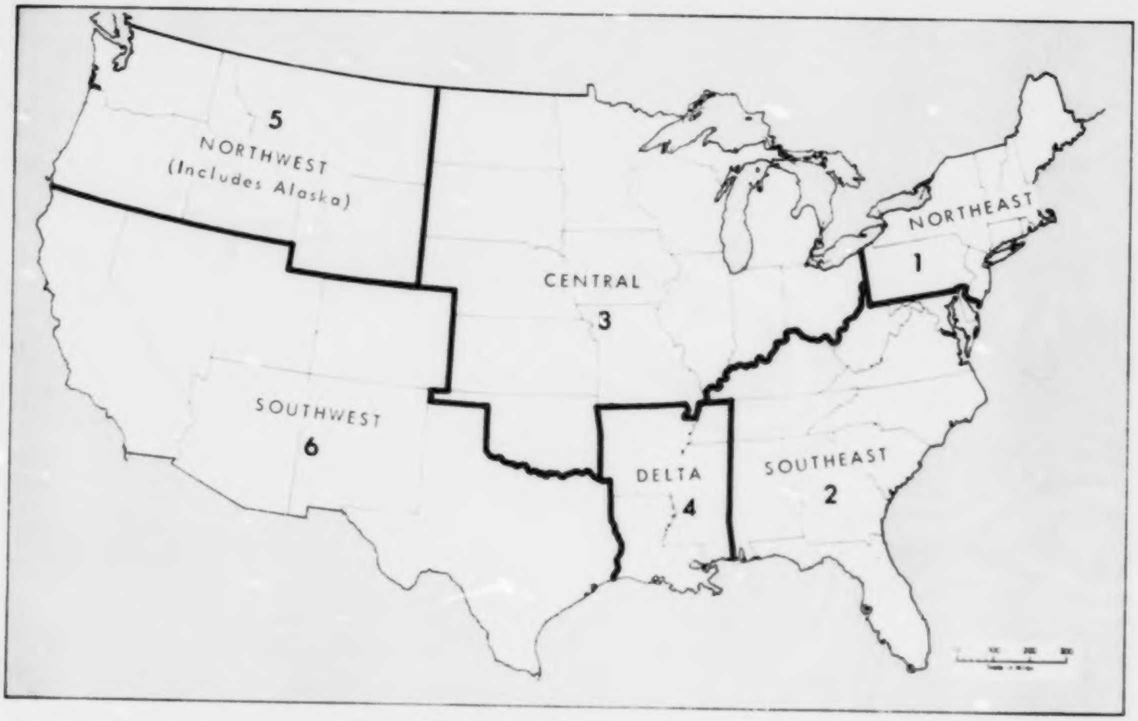

Figure 1. Geographical regions for human bone sampling

---

[1] Period during which death or surgical procedure occurred.

Table 1. Strontium-90 in human bone, July-September 1967—Continued

Region and State of residence	Bone type [a]	Age (years) [b]	Sex	Strontium-90 concentration (pCi/kg bone)	Calcium concentration (g/kg bone)	^{90}Sr/Ca (pCi/g)
Northeast:						
N. Y:	V	01	M	64.2 ± 9.4 [c]	26.6	2.41
Mass:	V	03	M	129.0 ± 9.6	22.8	5.65
Mass:	V	04	F	135.0 ± 14.0	37.1	3.63
Mass:	V	05	M	60.7 ± 8.2	28.5	2.12
Vt:	V	06	M	151.0 ± 9.5	33.5	4.50
Conn:	V, R	07	M	79.5 ± 11.0	28.7	2.77
Conn:	A	07	M	132.0 ± 13.0	33.4	3.95
Vt:	V	08	F	98.2 ± 10.0	35.9	2.73
N. J:	V, R	11	F	79.1 ± 8.4	36.0	2.19
Mass:	V	12	F	80.7 ± 11.0	40.6	1.98
Conn:	V	12	M	37.3 ± 6.9	18.0	2.07
N. Y:	V	12	F	112.0 ± 9.3	48.7	2.29
Conn:	V	13	F	181.0 ± 10.0	49.0	3.69
N. Y:	V	15	F	84.1 ± 8.0	43.8	1.92
Vt:	V	16	M	136.0 ± 11.0	46.3	2.93
N. Y:	V	16	M	248.0 ± 14.0	66.0	3.75
Pa:	V	18	F	115.0 ± 10.0	51.0	2.25
Conn:	V	18	F	216.0 ± 18.0	51.3	4.21
N. Y:	V	18	M	97.7 ± 7.9	41.0	2.38
Vt:	V	19	M	169.0 ± 13.0	47.0	3.59
Conn:	V	19	F	83.8 ± 9.2	39.8	2.10
N. Y:	V	19	M	160.0 ± 12.0	65.1	2.45
Vt:	V	20	F	123.0 ± 13.0	66.9	1.83
N. Y:	V	20	M	84.2 ± 7.9	31.1	2.70
Vt:	V	21	M	112.0 ± 13.0	53.8	2.08
Conn:	V, R	23	F	107.0 ± 11.0	46.9	2.28
Mass:	V	24	M	85.6 ± 7.0	35.4	2.41
N. Y:	V	24	M	126.0 ± 12.0	60.3	2.08
N. Y:	V	24	M	53.7 ± 11.0	40.8	1.31
Southeast:						
Ga:	V	00	M	196.0 ± 18.0	28.5	6.87
Ga:	V	03	F	79.4 ± 12.0	24.3	3.26
N. C:	V	05	M	167.0 ± 15.0	23.5	71.0
Md:	V	05	F	99.6 ± 12.0	34.5	2.88
N. C:	V	07	M	175.0 ± 15.0	19.0	9.21
S. C:	V	13	M	104.0 ± 11.0	32.9	3.16
S. C:	V	16	M	158.0 ± 12.0 [c]	39.4	4.01
Md:	V	16	F	182.0 ± 14.0	62.2	2.92
Md:	V	17	M	140.0 ± 20.0	52.9	2.64
Ga:	V	17	F	105.0 ± 11.0	49.7	2.11
S. C:	V	18	M	156.0 ± 13.0	48.5	3.21
S. C:	V	18	M	77.2 ± 8.0	31.6	2.44
S. C:	V	20	M	157.0 ± 12.0	52.7	2.97
Md:	V	20	M	148.0 ± 13.0	55.7	2.65
S. C:	V	20	M	110.0 ± 9.1	50.1	2.19
Md:	V	20	M	80.0 ± 10.0	42.8	1.88
Md:	V	20	M	84.5 ± 12.0	51.6	1.63
Md:	V	20	M	155.0 ± 10.0	48.8	3.17
Md:	V	22	M	131.0 ± 12.0	50.8	2.57
Ga:	V	22	F	117.0 ± 11.0	60.1	1.94
Md:	V	23	M	73.0 ± 7.2	53.4	1.36
Md:	V	23	M	79.3 ± 7.7	46.4	1.70
Md:	V	23	M	146.0 ± 12.0	57.1	2.55
Ga:	V	23	F	108.0 ± 12.0	52.8	2.04
Md:	V	23	M	137.0 ± 12.0	58.8	2.32
Md:	V	24	M	91.7 ± 10.0	54.3	1.68
Md:	V	24	M	73.2 ± 8.9	51.3	1.42
Md:	V	24	M	74.6 ± 10.0	70.8	1.05
Md:	V	24	M	126.0 ± 10.0	60.0	2.10
Md:	V	24	M	97.8 ± 12.0	56.3	1.73
Central:						
Wisc:	V	00	M	39.2 ± 11.0	27.3	1.43
Wisc:	V	01	M	131.0 ± 11.0	26.7	4.90
Wisc:	V	01	F	108.0 ± 15.0	31.9	3.38
Wisc:	V	02	F	97.6 ± 16.0	28.2	3.46
Wisc:	V	02	M	171.0 ± 17.0	29.7	5.75
Wisc:	V	03	F	118.0 ± 12.0	30.2	3.90
Iowa	V	06	M	54.8 ± 7.3	36.2	1.51
Ind:	V	07	F	158.0 ± 16.0	35.6	4.43
Minn:	V	07	F	32.6 ± 8.4	26.6	1.22
Ohio	V	10	M	100.0 ± 6.4	33.6	2.97
Ohio:	V	12	F	187.0 ± 14.0	63.6	2.94
Minn:	V	13	M	105.0 ± 10.0 [c]	44.3	2.37
Mich:	V	14	M	87.8 ± 10.0	37.0	2.37
Ohio:	V	15	F	72.5 ± 7.9	26.3	2.75
Ohio:	V	17	M	161.0 ± 10.0	51.4	3.13
Ohio:	V	18	M	153.0 ± 14.0	59.2	2.58
Ohio:	V	19	M	102.0 ± 10.0	44.6	2.28
Ohio:	V	19	M	141.0 ± 14.0	58.3	2.41
Mich:	V	21	F	170.0 ± 10.0	52.9	3.21
Ohio:	V	21	M	188.0 ± 16.0	72.6	2.58
Ohio:	V	21	F	159.0 ± 18.0	63.7	2.49
Mich:	V	22	F	112.0 ± 10.0	43.9	2.55
Ohio:	V	25	M	109.0 ± 12.0	56.6	1.92

Table 1. Strontium 90 in human bone, July-September 1967—Continued

Region and State of residence	Bone type [a]	Age (years) [b]	Sex	Strontium-90 concentration (pCi/kg bone)	Calcium concentration (g/kg bone)	^{90}Sr/Ca (pCi/g)
Delta:						
La:	V	02	M	148.0 ± 12.0	29.7	4.98
La:	V	09	M	72.8 ± 12.0	30.6	2.37
La:	A	12	F	144.0 ± 12.0	45.0	3.20
La:	V	13	M	79.8 ± 11.0	31.6	2.52
La:	V, R	14	F	66.9 ± 7.4	57.7	1.15
La:	V	15	M	62.3 ± 9.7	39.8	1.56
La:	V	21	M	117.0 ± 9.7	63.5	1.84
Northwest:						
Ore:	V	00	F	62.9 ± 7.2	58.0	1.08
Ore:	V	01	F	98.9 ± 7.6	54.9	1.80
Ore:	V	15	F	199.0 ± 15.0	62.4	3.18
Wash:	V	18	M	111.0 ± 9.8	44.3	2.50
Ore:	V	23	F	257.0 ± 17.0	50.3	5.10
Ore:	V	23	F	72.9 ± 7.9	45.1	1.61
Southwest:						
Tex:	V	00	F	153.0 ± 20.0	38.3	3.99
Tex:	V	02	F	52.1 ± 8.2	19.8	2.63
Calif:	V	06	M	36.7 ± 5.4	53.8	0.68
Tex:	FO	12	M	98.6 ± 11.0	53.4	1.84
Tex:	V	19	F	87.6 ± 9.1	52.4	1.67
Tex:	V	19	M	97.6 ± 10.0	36.5	2.67

[a] Type of bone: V, vertebrae; R, rib; FO, foot, A, arm.
[b] Age given as of last birthday prior to death.
[c] Two-sigma counting error.

Most specimens received to date have been vertebrae and ribs.

Laboratory procedures

The bones are analyzed at Northeastern Radiological Health Laboratory of the National Center for Radiological Health, at Winchester, Mass. Sample collection and preparation are explained elsewhere (*2*). Strontium-90 is measured by tributyl phosphate extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium-90 content is then calculated (*3*) from the yttrium-90 activity. For the purpose of maintaining analytical reproducibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples. To further check and maintain analytical accuracy, synthetic "bone ash" samples (calcium phosphate spiked with strontium-90) are analyzed periodically and cross-check analyses are carried out quarterly with the Health and Safety Laboratory of the AEC, which performs similar analyses.

The analytical results for strontium-90 in individual bones from persons dying during the third quarter (July–December) of 1967 are presented in table 1 in order of increasing age within each geographical region. These regions are indicated in figure 1. Reported values are given in picocuries of strontium-90 per kilogram of bone (as a rough indication of dose) and per gram of calcium (for comparison with other data and for purposes of model development). Two-sigma counting errors are reported for the bone concentration.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–5*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1966	September 1967
January–March 1967	June 1968
April–June 1967	September 1968

REFERENCES

(*1*) RIVERA, J. Strontium-90 in human vertebrae, 1962–1963. Radiol Health Data 5:511–513 (October 1964).

(*2*) WEISS, E. S., W. H. LAND, K. H. FALTER, and R. M. HALLISEY. Strontium-90 content of human bones, 1961–1963. Radiol Health Data 5:231–239 (May 1964).

(*3*) PUBLIC HEALTH SERVICE, NORTHEASTERN RADIOLOGICAL HEALTH LABORATORY. Analysis of environmental samples, chemical and radiochemical procedures, NERHL 64-1. Northeastern Radiological Health Laboratory, Winchester, Mass. (April 1964).

(*4*) GAFFNEY, G. W., R. M. HALLISEY, M. S. MILLER, and A. S. GOLDIN. Strontium-90 in human bone, 1962–1963. Radiol Health Data 5:620–628 (December 1964).

(*5*) HALLISEY, R. M., and M. A. WALL. Strontium-90 in human bone, 1964–1965. Radiol Health Data Rep 8:415–419 (August 1967).

Strontium–90 in Human Vertebrae, 1967[1]

Health and Safety Laboratory
Atomic Energy Commission

Since 1960, measurements of the strontium–90 content of foods and estimates of the daily intake of strontium–90 at New York City, Chicago, and San Francisco have been made by the Health and Safety Laboratory (HASL). Since 1961, measurements of the strontium–90 content of human vertebrae obtained from HASL by cooperating pathologists at the three cities have also been made. Data obtained from these programs have been used to construct models that attempt to explain the variation of strontium–90 concentrations in bone with age and time. The main purpose of the work is to provide estimates of the radiation dose to man that has resulted from the fallout from nuclear weapons tests. In attempting to construct the models it has become apparent that there are serious gaps in our knowledge of mineral metabolism especially that of children. The survey data have therefore been used, at times, to gain some insight into the metabolism of strontium by children. This approach is very difficult because of the small numbers of specimens that are available and the absence of an exact knowledge of the diet of the children from whom specimens were obtained. Because it is unlikely that much direct experimental data from tracer studies on children will ever be available, we will be forced to rely on the indirect evidence from survey results to construct our models.

A listing of the results obtained as part of this program through 1964, along with an interpretation of the data was given earlier (*1*). Results of the analyses of samples obtained in 1965 and 1966 were previously reported (*2*, *3*). Results of the analyses of samples obtained during 1967 are summarized in table 1 and are shown graphically in figure 1. Results of individual analyses are listed in tables 2 and 3.

Table 1. Strontium–90 to calcium ratios in human vertebrae

Age	New York City (pCi ^{90}Sr/g Ca)	San Francisco (pCi ^{90}Sr/g Ca)
<1 mo	—	0.87 (27)
1 mo–1 yr	*4.14 (9)	1.57 (19)
1–2	3.24 (5)	1.65 (3)
2–3	3.21 (5)	—
3–4	3.15 (3)	1.42 (2)
4–5	3.98 (4)	1.89 (2)
5–6	3.70 (2)	1.29 (3)
6–7	2.57 (1)	1.28 (1)
7–8	3.23 (5)	1.22 (2)
8–9	—	1.28 (2)
9–10	—	—
10–11	3.02 (2)	—
11–12	2.28 (2)	—
12–13	—	—
13–14	—	1.40 (1)
14–15	2.84 (2)	1.68 (2)
15–16	3.36 (2)	—
16–17	—	—
17–18	3.08 (4)	—
18–19	2.63 (9)	—
19–20	1.83 (2)	—
20–30	1.98 (12)	—
30–40	1.93 (8)	—
40–60	1.82 (20)	—
> 60	1.73 (14)	—

* Number in parentheses indicates number of specimens.

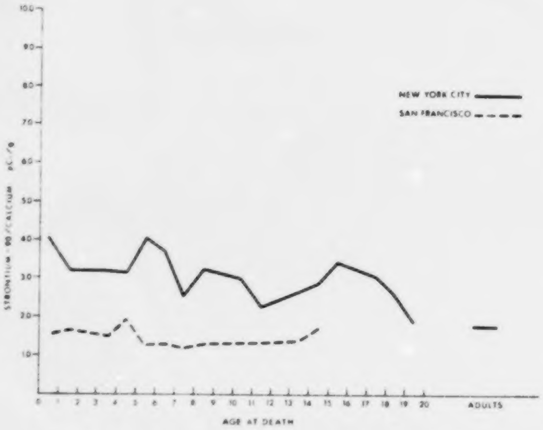

Figure 1. Strontium–90 to calcium ratios in human vertebrae during 1967

The pattern of strontium–90 concentrations in bone found in the 1967 specimens is not in conformity with those patterns previously seen.

---

[1] Material authored by Mr. J. Rivera, from Fallout Quarterly Summary Report, HASL–197, July 1, 1968. Available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va. 22151.

63

Table 2. Strontium-90 to calcium ratios of human vertebrae New York City residents, 1967

Age at death	Month of death	pCi ^{90}Sr/g Ca
7 months	7,10,12	[a] 4.55(3)
2 months	4,5,5,3,1,2	3.93(6)
1- 2 years	11	[b] 3.67
1- 2	4,9	3.21(2)
1- 2	11,12	3.05(2)
2- 3	5,10	3.32(2)
2- 3	8	3.08
2- 3	10	3.11
3- 4	5,7	2.89(2)
3- 4	2	3.67
4- 5	2,5	5.04(2)
4- 5	3,9	2.92(2)
5- 6	3,6	3.70(2)
6- 7	11	2.57
7- 8	3	3.03
7- 8	4	3.44
7- 8	7	4.02
7- 8	2	2.16
7- 8	11	3.46
10-11	3	3.40
10-11	7	2.61
11-12	7	3.06
11-12	10	1.49
14-15	6	3.65
14-15	8	2.03
15-16	9	3.51
15-16	8	3.21
17-18	6	2.32
17-18	4	3.43
17-18	8	3.46
17-18	9	3.11
18-19	7	1.92
18-19	3	2.73
18-19	7	2.54
18-19	7	2.40
18-19	7	2.90
18-19	7	4.19
18-19	3	2.67
18-19	9	2.13
18-19	9	2.21
19-20	6	2.03
19-20	9	1.62
20	5	2.54
20	2	2.24
20	7	1.96
22	5	2.32
22	7	1.88
22	5	1.46
23	4	1.76
24	7	1.89
24	5	1.76
25	1	2.03
28	9	2.08
28	2	1.88
30	6	2.07
30	7	1.49
31	5	2.25
33	6	2.13
33	5	1.80
35	5	1.68
35	6	2.19
39	6	1.79
40	7	1.80
41	8	1.40
41	9	1.74
45	12	1.67
45	5	1.79
46	5	1.94
47	5	1.49
48	6	1.78
49	7	2.64
50	7	1.83
51	1	1.46
52	10	2.94
52	5	1.56
53	2	1.54
54	5	2.75
55	1	1.70
55	4	1.94
56	1	1.39
56	6	1.52
58	1	1.51
60	6	1.67
63	7	1.77
67	5	1.56
68	1	0.77
70	3	2.00
70	7	1.71
71	3	1.99
71	6	1.42
72	4	1.76
73	4	2.04
77	8	2.86
82	9	1.57
83	3	1.33
83	6	1.82

[a] Number in parentheses indicates number of specimens.
[b] Only one specimen.

Table 3. Strontium-90 to calcium ratios of human vertebrae, San Francisco residents, 1967

Age at death	Month of death	pCi ^{90}Sr/g Ca
1 week	1,1,1,1,2,2	[a] 0.88(6)
1	3,4,4,9,9	.98(5)
1	5,5,6,7,7,7	.90(6)
1	8,8,8,8,8	.78(5)
1	8,8,9,10,10	.82(5)
1 month	1,1,2,3,4	1.18(5)
1	6,9	.66(2)
3	2,5,6,8,8,10	1.63(6)
8	2,3,7,9,10,12	2.15(6)
1- 2 years	2,3,7	1.65(3)
3- 4	1	[b] 1.74
3- 4	10	1.29
4- 5	3	2.21
4- 5	6	1.57
5- 6	3	1.51
5- 6	10	1.15
5- 6	10	1.21
6- 7	3	1.28
7- 8	1	.71
7- 8	4	1.73
8- 9	2	1.22
8- 9	7	1.34
13-14	5	1.40
14-15	9	1.65
14-15	8	1.71

[a] Number in parentheses indicates number of specimens.
[b] Only one specimen.

The peak in strontium-90 concentrations usually seen in young children was not evident; the concentrations were, however, as expected higher than those found in specimens from adults. Strontium-90 concentrations from New York City residents were about three times higher than corresponding specimens obtained in San Francisco. This persistent relative difference reflects the fact that strontium-90 intakes in New York City have been continually about three times as great as the intakes in San Francisco as can be seen from figure 2 where the results of our diet surveys are shown graphically.

Infants

A relatively large number of specimens were obtained in San Francisco from infants who died after less than 1 week of life. The average

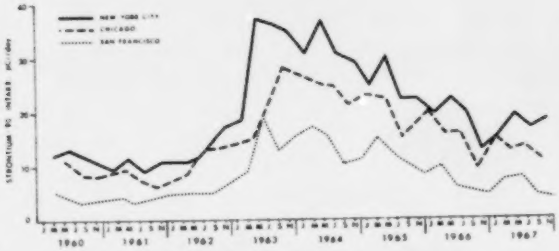

Figure 2. Daily intake of strontium-90

strontium-90 to calcium ratio found in these specimens was 0.87 pCi/g Ca. Since the average diet of mothers from the San Francisco area was probably not greater than about 7 pCi/g Ca (figure 2), the mother's diet-fetal bone observed ratio is probably not less than 0.12. This result is in general agreement with the hypothesis that placental discrimination is about 0.25 and hence the total discrimination from mother's diet to fetal bone is expected to be 0.5 x 0.25 = 0.12.

The expected concentrations of strontium-90 in the bones of children who died during the first year of life were calculated using the relation derived in a prior publication (*3*):

$$X_{0-1} = 0.065\ Z_m + 0.15\ Z$$

where X_{0-1} is the average strontium-90 to calcium ratio of the bones of infants up to 1 year of age. Z_m is the average strontium-90 to calcium ratio of the mother's diet for the 3-month period prior to birth and Z is the average strontium-90 to calcium ratio of the child's diet during the first year of life. The results along with the observed values are shown in table 4. The agreement between predicted and observed results parallels what has been obtained in the past.

Table 4. Predicted and observed ratios of strontium-90 to calcium in infants

	pCi ^{90}Sr/g Ca	
	Predicted	Observed
New York City	3.4	4.1
San Francisco	1.2	1.6

Adults

A formula derived in (*1*) for calculating the expected strontium-90 to calcium ratio of vertebrae from adults is:

$$X_n = 0.9\ X_{n-1} + 0.02\ Z_{n-1}$$

where X_n is the strontium-90 to calcium ratio of the vertebrae at the beginning of year 'n', X_{n-1} is the ratio at the beginning of year 'n-1' and Z_{n-1} is the strontium-90 to calcium ratio of the diet during the year. In deriving this expression it was assumed that the rate of replacement of calcium in vertebrae is 8 percent per year and that the bone-diet observed ratio was 0.25.

Since the observed bone concentrations of adults are average values obtained from people who died at different months of the year, the expected concentration for New York City residents at the middle of the year was calculated. The result was:

$$X_n = 0.9\ (2.07) + 0.02\ (17) = 2.20\ \text{pCi/g Ca}$$

The observed average value was 1.85 pCi/g Ca.

Children

The pattern of the contamination of children's bones with strontium-90 can be seen in tables 5 and 6.

Table 5. Average strontium-90 to calcium ratio in children's bones (New York City)

Age range	1961	1962	1963	1964	1965	1966	1967
0-4	2.83	3.06	5.13	5.50	6.45	4.98	3.44
4-12	1.38	1.70	2.02	3.46	3.50	3.66	3.13
12-20	1.28	1.56	2.09	2.98	3.54	2.93	2.75

Table 6. Average strontium-90 to calcium ratio in diet (New York City)

	1961	1962	1963	1964	1965	1966	1967
Yearly	10	13	31	32	25	19	17
	1960-1961	1961-1962	1962-1963	1963-1964	1964-1965	1965-1966	1966-1967
Mid-year to mid-year	11	11	21	34	16	22	17

From these data one can see that the increase in diet levels from 1962 to 1963 produced a sharp increase in bone strontium-90 concentrations of young children and a lesser increase in the bone levels of older children. The 1967 bone levels of young children, however, are much lower than those observed in 1966 although the diet levels were practically the same for the 2 years. The significance of these changes in the light of the models proposed by Fletcher, Loutit and Papworth (*4*), Beninson et al (*5*), and this laboratory (*6*) may be the subject of a future report.

When this formula was applied to calculate expected values for 1966, the result was 2.35 pCi/g Ca as compared to the observed value of 2.07 pCi/g Ca.

If the bone-diet observed ratio is 0.25 then one would expect bone levels to continue to increase until they reach the equilibrium point where they have a strontium-90 to calcium ratio equal to one-fourth that of the diet. Apparently, however, during 1966 and 1967 vertebrae from adults had declining strontium-90 to calcium ratios. Although admittedly the scatter of values about the mean strontium-90 to calcium ratio is so great as to preclude granting statistical significance to this decline, it appears that the model may have to be revised, and the possibility that the previously achieved good agreement between observed and calculated strontium-90 bone levels is fortuitous, or at best, works only when diet strontium-90 levels are increasing.

Probability distribution

A number of investigators (*7, 8, 9*) have pointed out that when the frequency distribution of bone strontium-90 to calcium ratios are plotted on arithmetic probability paper and on logarithmic probability paper the 'fit' appears to be better on the logarithmic paper. They conclude therefore, that geometric means and standard deviations should be given to characterize bone strontium-90 to calcium ratios of populations rather than arithmetic means and standard deviations. This conclusion is important because if the distribution is log normal then a larger fraction of the population will have strontium-90 body burdens 'n' times the mean than would be calculated assuming a normal distribution. A criticism of this conclusion is that the "eyeball goodness of fit" test is not always reliable. It should also be pointed out that in most cases the samples for which frequency distributions were calculated were not homogeneous. If the sample population had included a non-random number of children or consisted of specimens obtained in a non-random way from areas where the diet strontium-90 to calcium ratios were quite different, adventitiously bizarre distributions might be expected.

To obviate some of these difficulties, specimens were obtained from 42 individuals who were over 30 years of age at death and who could reasonably be assumed to have lived in New York City for a considerable length of time just prior to death. The results of the analyses of the 42 specimens were averaged and the standard deviation from the mean was calculated. Using this mean and standard deviation, a straight line was drawn on arithmetic probability paper. The points for the observed cumulative frequency distribution were then plotted on the graph which is shown in figure 3. A similar procedure was used to calculate the geometric mean and geometric standard deviation of the population and to draw the straight line on logarithmic probability paper shown in the bottom of figure 3. As before, the observed cumulative frequencies were also indicated as points on the graph.

Although it appears that the 'fit' is better on the log-normal paper, it was not appreciably better. A more objective test of the "goodness of fit" of the data to the two hypothetical distributions was attempted by applying the non-parametric Kolmogorov-Smirnov (*10*) test. The result was that at a 5 percent level of significance the hypothesis that the sample was drawn from a normal distribution could not be rejected. The test also showed that the hypothesis of the sample being drawn from a log-normal distribution could not be rejected. Although according to Massey (*11*) the K-S test is more powerful than the Chi square test, the test was quite weak. Thus, the assertion that the distribution is normal may be wrong 68 percent of the time while the assertion that the sample was drawn from a log-normal distribution may be wrong 83 percent of the time.

66

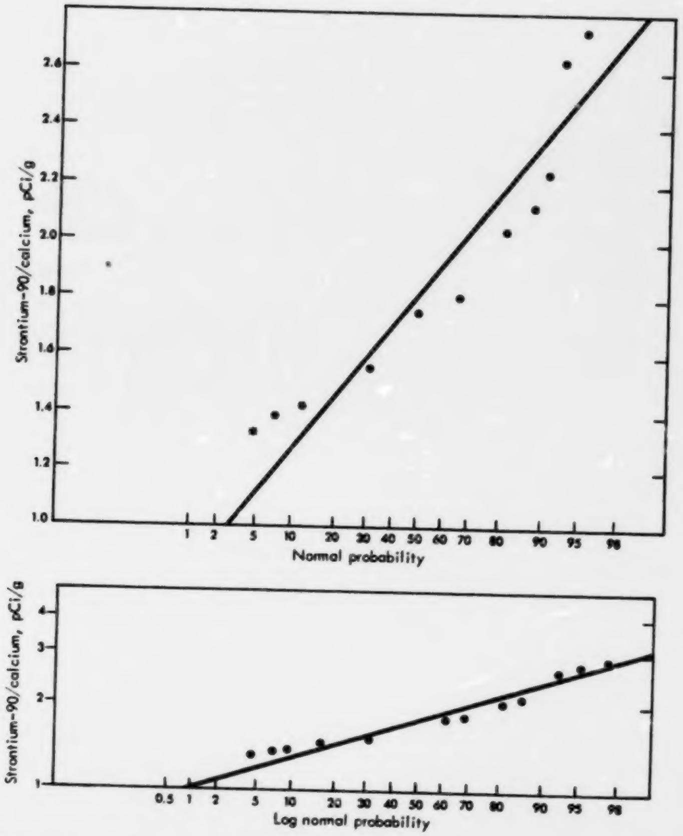

Figure 3. Frequency distribution of strontium-90/calcium ratios in adult vertebrae, New York City, 1967

Conclusions

From this exercise it is concluded that it is quite difficult to prove that bone strontium-90 to calcium ratios from a geographically homogeneous sample of adults are log-normally distributed. It is probably justified, however, to assume a long-normal distribution for radiation hazard evaluations.

REFERENCES

(*1*) RIVERA, J. and J. H. HARLEY. The HASL bone program 1961–1964, HASL-163. U.S. ATOMIC ENERGY COMMISSION (August 1965).

(*2*) RIVERA, J. Strontium-90 in human vertebrae-1965 results, HASL-172:I-141 U.S. ATOMIC ENERGY COMMISSION (July 1966).

(*3*) RIVERA, J. Strontium-90 in human vertebrae-1966 results, HASL-182:I-10 U.S. ATOMIC ENERGY COMMISSION (July 1967).

(*4*) FLETCHER, W., J. F. LOUTIT and D. G. PAPWORTH. Interpretation of levels of strontium-90 in human bone. Brit Med J 2:1225–1230 (November (1966).

(*5*) BENINSON, D., E. RAMOS, M. de BENISON, A. KRAMER, and C. MENOSSI. Strontium-90 levels in the diets and bones of children-progress report 1967, HASL-183:I-22. U.S. ATOMIC ENERGY COMMISSION (October 1967).

(*6*) RIVERA, J. Predicting strontium-90 concentrations in human bone. Strontium Metabolism, J. M. A. Lenchan, J. F. Loutit and J. H. Martin, Editors. Academic Press, London & New York (1967).

(*7*) MAREI, A. N., V. A. KNIZHNIKOV, E. I. YARTSEV, and E. I. MOISEENKO. Strontium-90 content in bone tissue of the population of the Soviet Union in 1959–1963. State Committee on Use of Atomic Energy, USSR, Atomizdat, Moscow (1964).

(*8*) HALLISEY, R. M. and M. A. WALL. Strontium-90 in human bones 1964–1965. Radiol Health Data Rep 8:415–419 (August 1967).

(*9*) SCHUBERT, J., A. BRODSKY, and S. TYLER. The log-normal function as a stochastic model of the distribution of strontium-90 and other fission products in humans. Health Physics 11:1187–1204 (November 1967).

(*10*) ONG, L. D. and P. C. Le CLARE. The Kolmogorov-Smirnov test for the log-normality of sample cumulative requency distributions. Health Physics 14:376 (April 1968).

(*11*) MASSEY, F., JR. The Kolmogorov-Smirnov test for goodness of fit. Amer Statist Ass J 46:68 (1951).

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major AEC installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the AEC Manual.[1]

Summaries of data from the environmental radioactivity monitoring reports follow for the National Reactor Testing Station and Oak Ridge Area.

---

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation," contains essentially the standards published in Chapter 0524 of the AEC Manual.

---

1. National Reactor Testing Station[2]
July–December 1967

Health and Safety Division
U.S. Atomic Energy Commission
Idaho Falls, Idaho

Data from the environmental monitoring network on and around the National Reactor Testing Station (NRTS) in eastern Idaho revealed that NRTS operations during the second half of 1967 did not contribute significantly to environmental radiation or radioactivity concentration levels. These levels remained well below the levels defined as thresholds of concern by the Federal Radiation Council (FRC). The radiation protection standards used at the NRTS, which are established in AEC Manual Chapter 0524, are based on FRC recommendations. In choosing applicable standards for drinking water, credit has been taken for the fact that no significant quantities of radium–226 or radium–228 have been released to the environs by NRTS operations. The concentrations of radioactivity reported include contributions from all sources. No attempt has been made to separate activity contributed by NRTS operations from that contributed by natural sources of radioactivity or by fallout from weapons debris. Samples of air, water, wheat and milk are collected routinely at stations shown in figure 1. The results of the analyses performed on the air, water and milk samples are shown in table 1.

---

[2] Summarized from "Environmental Monitoring Report No. 21, July-December and Annual Summary for 1967," U.S. Atomic Energy Commission, Idaho Operations Office, Health and Safety Division, National Reactor Testing Station.

68

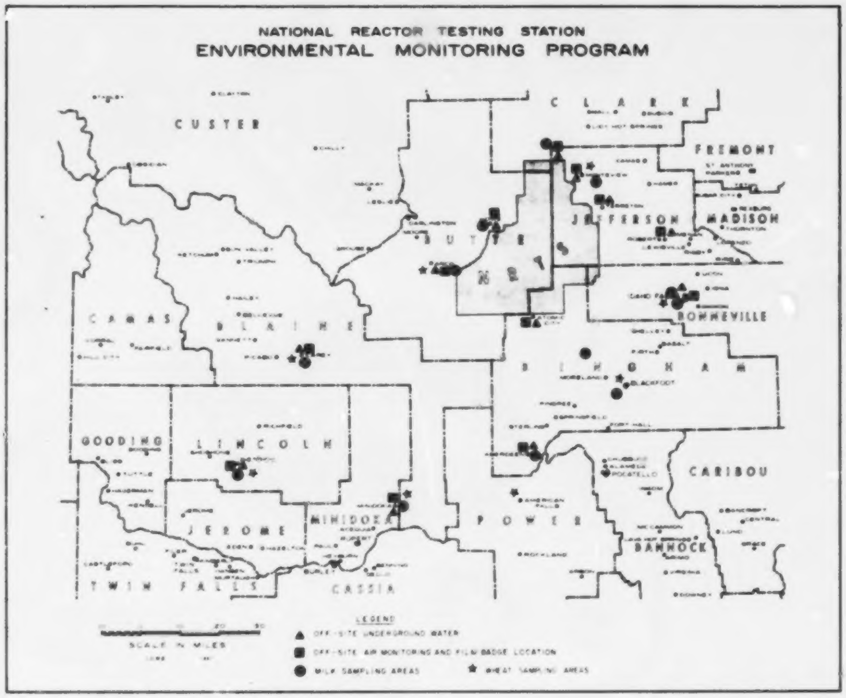
NATIONAL REACTOR TESTING STATION
ENVIRONMENTAL MONITORING PROGRAM
CUSTER
CLARK
FREMONT
JEFFERSON
MADISON
BUTTE
NRTS
BONNEVILLE
CAMAS
BLAINE
BINGHAM
GOODING
LINCOLN
CARIBOU
JEROME
MINIDOKA
POWER
BANNOCK
TWIN FALLS
CASSIA
SCALE IN MILES
LEGEND
▲ OFF-SITE UNDERGROUND WATER
■ OFF-SITE AIR MONITORING AND FILM BADGE LOCATION
● MILK SAMPLING AREAS
★ WHEAT SAMPLING AREAS

Figure 1. Environmental monitoring stations, National Reactor Testing Station

Offsite water monitoring

Low-level liquid wastes from various operating facilities at the NRTS are released to the ground-water table through disposal wells and ponds located near each facility. Before disposal the liquid wastes are carefully monitored at the NRTS and, as an added safeguard, offsite underground water samples are collected and analyzed regularly from those populated areas nearest the site boundaries. Samples from these locations, as shown on the accompanying map, plus the onsite samples provide adequate information on the underground water leaving the NRTS. During the second half of 1967, one sample was collected from each of 12 sampling stations. The average concentrations of alpha and beta particle emitters were less than 3 percent and 7 percent of the respective AEC standards. The alpha radioactivity is attributed primarily to radioactive elements which are naturally present in the environment.

Onsite water monitoring

Onsite samples were taken from the plant production wells in order to detect and define possible sources of contamination. During the summer one additional sampling station was added to the 22 regular stations. A total of 468 samples were analyzed in 1967 and 263 for the last 6 months of 1967. These samples are collected on a biweekly basis. Analyses of these samples showed that average concentrations of alpha and beta-particle emitters were no more than 0.1 percent and 0.2 percent of their respective AEC standards.

Air monitoring

During the last half of 1967, 206 air samples were collected and evaluated for airborne alpha-particle emitters. A gross alpha-particle determination was made on filter paper samples after a sufficient time had elapsed to permit the decay of the short-lived daughter products

Table 1. Environmental monitoring data for NRTS, July–December 1967

Type of sample and units	July–December 1967						AEC radiation protection standard
	Number of stations	Approximate frequency of collection	Type of analysis	Minimum level of detection	Maximum radioactivity of single sample	Average radioactivity per sample	
Offsite underground water, (pCi/liter)	12	Semiannual	Alpha	3	4	<3	100
			Beta	6	10	<7	100
Onsite production well water, (pCi/liter)	22	Biweekly	Alpha	3	7	<4	3.000
			Beta	6	36	<8	3,000
Offsite air, (pCi/m^3)	12	Continuous	Beta-gamma	1.6	26	<4	100
			Iodine-131	3.6	15	<4	100
Offsite milk, (pCi/liter)	12	Monthly	Iodine-131	20	20	<20	100
			Strontium-90	1.5	7	<4	200
Offsite area monitoring badges, (mR)	12	Semiannual	Gamma	10	80	<39	170/yr

of radon and thoron. The filter paper samples were counted for alpha-particle emission by scintillation counters. The average measured concentrations of alpha radioactivity in air was .002 pCi/m^3 or less than 7 percent of the AEC standard. The radiation protection standard used is that for uncontrolled areas and for gross alpha radioactivity for which no analyses for specific radionuclides have been made. The alpha radioactivity is attributed primarily to long-lived radioactive elements naturally present in the environment.

Results of the data reported from the 12 offsite radiation telemetry stations indicate that the average concentrations of gaseous iodine–131 and particulate gross beta radioactivity in the atmosphere were less than 4 percent of the AEC radiation protection standards.

Offsite milk monitoring

Routine analyses of iodine–131 and strontium–90 concentrations in milk continued during the second half of 1967. As indicated in table 1, the average iodine–131 levels do not exceed 21 percent of the permissible concentrations derived from FRC guides. Strontium–90 concentrations were less than 3 percent of the AEC standard.

Gamma radiation levels

Seminannual measurements of external gamma radiation levels were made with thermoluminescent dosimeters (TLD) at 12 offsite locations during the second half of 1967.

Natural background radiation levels at TLD locations vary, but studies made prior to nuclear operations at the NRTS showed that normal background levels were of the order of 100–150 mR/yr. This indicates that NRTS operations have not contributed significantly to the environmental radiation levels of the surrounding areas.

Wheat monitoring

Eight wheat samples were collected from southeastern Idaho during the 1967 grain harvest. The strontium–90 levels ranged from 1 to 17 pCi/kg (dry weight) with an average of 8 pCi/kg. Analysis for cesium–137 showed an average concentration of 21 pCi/kg. Routine analysis of the wheat samples did not detect the presence of manganese–54. When the wheat concentrations are compared to the RCG value for water, it is evident that wheat does not contribute a significant amount to the local radiation dose.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December and calendar year 1966	September 1967
January–June 1967	March 1968

2. Oak Ridge Area[3]
July–December 1967

Union Carbide Nuclear Company
Oak Ridge, Tennessee

Oak Ridge Area is a complex, made up primarily of the Y-12 Plant, the Oak Ridge National Laboratory (ORNL), and the Oak Ridge Gaseous Diffusion Plant (ORGDP).

Radioactive waste materials arising from the operation of atomic energy installations in the Oak Ridge area are collected, treated, and disposed of according to their physical states. Solid wastes are buried in a Conasauga shale formation which has a marked ability to fix radioactive materials by an ion exchange mechanism. Liquid wastes which contain long-lived fission products are confined in storage tanks or are released to trenches located in the Conasauga shale formation. Low-level liquid wastes are discharged, after preliminary treatment, to the surface streams. Air that may become contaminated by radioactive materials is exhausted to the atmosphere from several tall stacks after treatment by means of filters, scrubbers, and/or precipitators.

Air monitoring

Atmospheric contamination by radioactive materials occurring in the general environment of East Tennessee is monitored by two systems of monitoring stations. One system consists of nine stations which encircle the plant areas (figure 2) and provide data for evaluating the impact of all Oak Ridge operations on the immediate environment. A second system consists of eight stations encircling the Oak Ridge area at distances of from 12 to 75 miles (figure 3). This system provides data to aid in evaluating local conditions and to assist in determining the spread or disposal of contamination should a major incident occur.

Sampling for radioactive particulates is carried out by passing air continuously through a filter paper. Average concentrations are presented in tables 2 and 3. Airborne radioactive iodine is monitored in the immediate environment of the plant areas by passing air through a cartridge containing activated charcoal.

During the July–December 1967 surveillance period, 234 samples were collected from perimeter monitoring stations and analyzed for iodine-131. Of these, the maximum concentration detected was 0.22 pCi/m^3, the minimum was less than 0.010 pCi/m^3 and the average was 0.02 pCi/m^3. The radiation protection

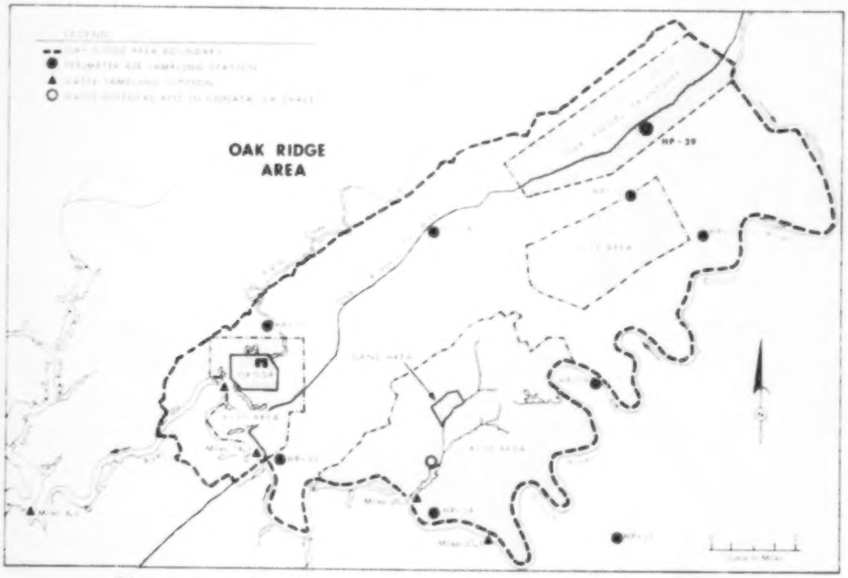

Figure 2. Oak Ridge area environmental sampling locations

---

[3] Summarized from Environmental Levels of Radioactivity for the Oak Ridge Area, Report Period, July-December 1967. Health Physics and Safety Section, Health Physics Division, Oak Ridge National Laboratory.

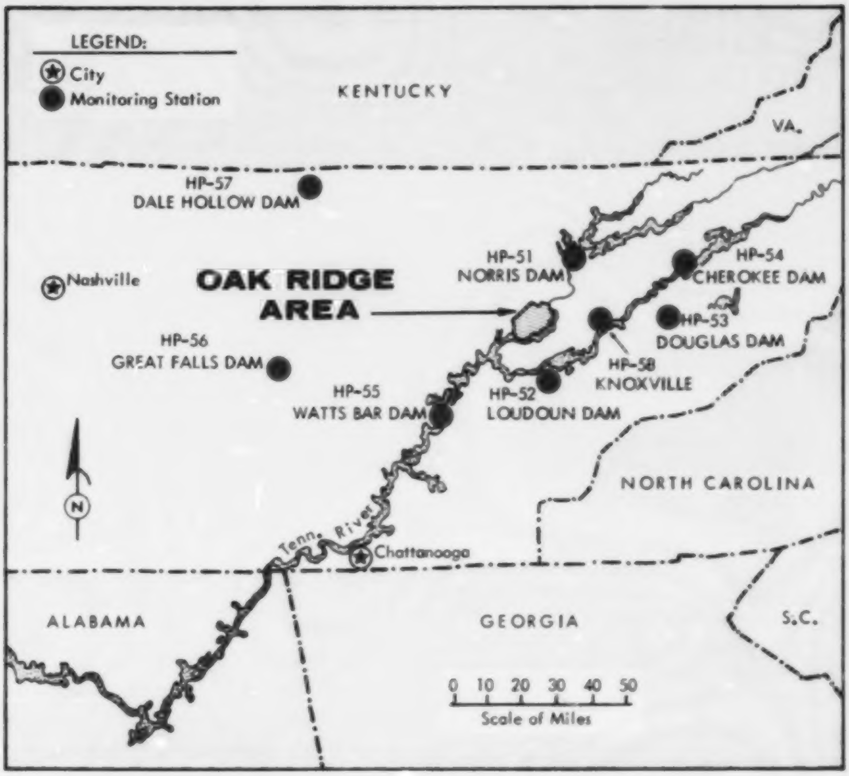
LEGEND:
City
Monitoring Station
KENTUCKY
VA.
HP-57
DALE HOLLOW DAM
HP-51
NORRIS DAM
HP-54
CHEROKEE DAM
Nashville
OAK RIDGE AREA
HP-53
DOUGLAS DAM
HP-56
GREAT FALLS DAM
HP-58
KNOXVILLE
HP-55
WATTS BAR DAM
HP-52
LOUDOUN DAM
N
NORTH CAROLINA
Tenn. River
Chattanooga
ALABAMA
GEORGIA
S.C.
0 10 20 30 40 50
Scale of Miles

Figure 3. Remote air monitoring stations, Oak Ridge area

standard specified in the AEC Manual for iodine-131 in the ambient atmosphere in uncontrolled areas is 100 pCi/m^3.

Milk monitoring

Raw milk is monitored for iodine-131 and strontium-90 by the collection and analysis of samples from 12 sampling stations located within a radius of 50 miles of ORNL. Samples are collected weekly at each of eight stations located on the fringe of the Oak Ridge area. Four stations, located more remotely with respect to the Oak Ridge operations, are sampled at a rate of one station each week. The purpose of the milk sampling program is twofold; first, samples collected in the immediate vicinity of the Oak Ridge area provide data by which one may evaluate possible exposure to the neighboring population resulting from waste releases from Oak Ridge operations; second, samples collected at the more remote stations provide background data which are essential in establishing the proper index for the evaluation of data obtained from local samples. The concentrations of iodine-131 and strontium-90 detected in raw milk samples during the period are given in table 4.

Water monitoring

Large volume, low-level liquid wastes originating at ORNL are discharged after some preliminary treatment, into the Tennessee River system by way of White Oak Creek and the Clinch River. Liquid wastes originating at the ORGDP and Y-12 Plant are discharged to Poplar Creek and thence to the Clinch River. Releases are controlled so that resulting average concentrations in the Clinch River comply with AEC radiation protection standards. The radioactivity concentration from White Oak Creek is measured, and concentration values for the Clinch River are calculated on the basis of the dilution provided by the river.

Table 2. Long-lived gross beta radioactivity of particulates in air Oak Ridge area, July–December 1967

Perimeter stations				Remote stations			
Station number (figure 1)	Number of samples	Average conc. (pCi/m³)	Percent of AEC standard [a]	Station number (figure 2)	Number of samples	Average conc. (pCi/m³)	Percent of AEC standard [a]
HP-31	27	0.036	0.04	HP-51	27	0.031	0.03
HP-32	27	.071	.07	HP-52	27	.029	.03
HP-33	27	.031	.03	HP-53	27	.056	.06
HP-34	27	.039	.04	HP-54	27	.028	.03
HP-35	26	.033	.03	HP-55	26	.024	.02
HP-36	188	.072	.07	HP-56	26	.026	.03
HP-37	27	.023	.02	HP-57	27	.025	.03
HP-38	27	.058	.06	HP-58	27	.035	.04
HP-39	27	.038	.04				
Average		0.045	0.05	Average		0.032	0.03

[a] The applicable AEC Radiation Protection Standard is 100 pCi/m³.

Table 3. Long-lived gross alpha radioactivity of particulates in air Oak Ridge area, July–December 1967

Perimeter stations				Remote stations			
Station number (figure 1)	Number of samples	Average conc. (pCi/m³)	Percent of AEC standard [a]	Station number (figure 2)	Number of samples	Average conc. (pCi/m³)	Percent of AEC standard [a]
HP-31	27	0.002	0.10	HP-51	27	0.002	0.10
HP-32	27	.004	.20	HP-52	27	.002	.10
HP-33	27	.002	.10	HP-53	27	.002	.10
HP-34	27	.002	.10	HP-54	27	.001	.05
HP-35	26	.003	.15	HP-55	26	.002	.10
HP-36	188	.009	.45	HP-56	26	.002	.10
HP-37	27	.002	.10	HP-57	27	.001	.05
HP-38	27	.002	.10	HP-58	27	.003	.15
HP-39	27	.003	.15				
Average		0.003	0.15	Average		0.002	0.10

[a] The applicable AEC Radiation Protection Standard for natural uranium in air is 2 pCi/m³.

Table 4. Radionuclides in raw milk, Oak Ridge area, July–December 1967

Radionuclide and location	Concentration (pCi/liter)		
	Maximum	Minimum [a]	Average
Iodine-131			
Immediate environs	13	<10	5.0
Remote environs	<10	<10	5.0
Strontium-90			
Immediate environs	50	9.0	28
Remote environs	34	14	25

[a] The minimum detectable concentrations of iodine-131 and strontium-90 in milk are 10 pCi/liter and 2 pCi/liter, respectively. In averaging, one-half of the minimum detectable concentration was used for all samples showing an activity less than this Concentration.

Water samples are taken at a number of locations in the Clinch River, beginning at a point above the entry of wastes into the river and ending at Center's Ferry near Kingston, Tenn. Stream gauging operations are carried on continuously to obtain dilution factors for calculating the probable concentrations of wastes in the river.

Samples are analyzed for the long-lived beta particle emitters, uranium, and the transuranic alpha-particle emitters.

Table 5. Concentrations of major radionuclides in the Clinch River July–December 1967

Radionuclide	Average concentration (pCi/liter)		
	Location on Clinch River [a]		
	Mile: 23.1 [b] (Upstream)	Mile: 20.8 [c] (Outfall)	Mile: 4.5 (Downstream)
Strontium-90	0.4	0.6	1.4
Cerium-144	< .1	< .1	0.2
Cesium-137	< .1	.2	1.4
Ruthenium-106	.2	.4	0.5
Cobalt-60	ND	.2	.7
Zirconium-niobium-95	ND	< .1	.1
Gross beta	.7	8.0	4.4

[a] The location on Clinch River is given in terms of the distance upstream from the Tennessee River. See figure 1.

[b] Sampling station moved from Clinch River mile 41.5 to Melton Hill Dam CRM 23.1 about January 1, 1966.

[c] The concentrations at mile 20.8 are not measured directly but the values are calculated based on the levels of waste released and the dilution provided by the river.

ND, nondetectable.

Analyses are made of the effluent for the long-lived radionuclides only, since cooling time and hold-up time in the waste effluent system are such that short-lived radionuclides are normally not present. The average concentrations of major radionuclides in the Clinch River are given in table 5 for the period from July through December 1967.

Two quarterly composite water samples from the Clinch River were analyzed for uranium during this period. For both samples, the uranium concentrations were less than 1 pCi/liter the level of detectability. The AEC radiation protection standard for natural uranium in water released to unrestricted areas is 2 x 10^4 pCi/liter.

Gamma measurements

External gamma radiation levels are measured monthly at a number of locations in the Oak Ridge area. Measurements are taken with a Geiger-Mueller tube at a distance of 3 feet above the ground. The results are shown in table 6 in terms of mR/hr.

Table 6. External gamma radiation levels [a], Oak Ridge area, July–December 1967

Location	Average exposure rates (mR/hr)
Solway Gate	0.011
Y-12, East Portal	.011
Newcomb Road	.011
Gallaher Gate	.010
White Wing Gate	.011
Five locations	0.011

[a] The background in the Oak Ridge area, determined in 1943, was approximately 0.012 mR/hr.

Discussion of data

The average air contamination levels for gross beta radioactivity, as shown by the continuous air monitoring filter data, for both the immediate and remote environs of the plants (figures 2 and 3) were 0.05 percent and 0.03 percent, respectively, of the AEC radiation protection standard for populations in the neighborhood of a controlled area.

The average air contamination levels for gross alpha radioactivity, as shown by the continuous air monitoring filter data, for the immediate and remote environs of the plants were 0.15 percent and 0.10 percent, respectively, of the AEC radiation protection standard for natural uranium for application to populations in the neighborhood of a controlled area.

The average concentration of iodine–131 in air in the immediate environs of the plants was 0.020 pCi/m^3. This is approximately 0.02 percent of the AEC radiation standard for populations in the neighborhood of a controlled area.

The average concentrations of iodine–131 in raw milk in the immediate and remote environs of the Oak Ridge area were 5 pCi/liter. This level falls within the limits of FRC Range I if the average intake per individual is assumed to be 1 liter of milk per day.

The average concentrations of strontium–90 in raw milk in the immediate and remote environs of the controlled area were 28 pCi/liter and 25 pCi/liter, respectively. These levels fall near the lower limit of FRC Range II for transient rates of daily intake of strontium–90 for application to the average of suitable samples of an exposed population.

The calculated average concentration of gross beta radioactivity in the Clinch River at mile 20.8 (the point of entry of most of the wastes) and the measured average concentration at mile 4.5 (near Kingston, Tenn.) were 8 pCi/liter and 4.4 pCi/liter, respectively. These values are 0.67 percent and 0.49 percent of the weighted average AEC radiation protection standards. The average concentration of transuranic alpha particle emitters in the Clinch River at mile 20.8 was 0.11 pCi/liter which is approximately 0.01 percent of the weighted average AEC radiation protection standard.

The average activity of natural uranium materials in the Clinch River, reflecting the effects of all Oak Ridge plants, was less than 0.01 percent of the AEC radiation protection standard for natural uranium.

The average external gamma radiation measured in the town of Oak Ridge and at the perimeter of the Oak Ridge area was 0.011 mR/hr, which is approximately the same as that level measured during the period prior to Oak Ridge operations.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1966	August 1967
January–June 1967	July 1968

Reported Nuclear Detonations, September 1968

The U.S. Atomic Energy Commission announced that the United States had recorded seismic signals originating from the Soviet underground nuclear test area in the Semipalatinsk region on September 5, 1968. The signals were equivalent to those of a nuclear test in the low-intermediate yield range (20–200 kilotons TNT equivalent).

Announcements were also made by the U.S. Atomic Energy Commission of two nuclear tests, one of low-intermediate yield (20 to 200 kilotons TNT equivalent) on September 6, 1968 and one of low yield (less than 20 kilotons TNT equivalent) on September 12, 1968. Both were conducted underground by the Atomic Energy Commission at its Nevada Test Site.

A nuclear test of low-intermediate yield (20–200 tons TNT equivalent) was conducted underground September 17, 1968, by the Atomic Energy Commission at its Nevade Test Site as part of the Plowshare Program to develop peaceful uses for nuclear explosions. This test was one of a series to develop nuclear explosives for use in excavation experiments.

The U.S. Atomic Energy Commission also announced a nuclear test of low yield (less than 20 kilotons TNT equivalent) that was conducted underground by the Atomic Energy Commission at its Nevada Test Site on September 24, 1968.

75

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

A PILOT SURVEY OF X-RADIATION EMISSIONS FROM COLOR TELEVISION RECEIVERS IN PINELLAS COUNTY, FLORIDA. *Technical Services Branch, National Center for Radiological Health*, Vol. 9, October 1968, pp. 525–530.

A pilot survey was conducted in Pinellas County, Florida, in November 1967 to evaluate methodology and techniques for use in determining the effectiveness of General Electric Company's modification program of color television receivers and in assessing the total radiation mission situation for television sets of all manufacturers. The instrument used was designed by the National Center for Radiological Health to facilitate rapid home surveys. To further document the source, size, shape and intensity of emissions, radiographic films were exposed on selected receivers.

The primary object of this survey was to evaluate the effectiveness of the downward beam modification program. Within the limits of this survey, the General Electric Company's downward beam modification program was found effective. The initial survey determined that 43 of the 148 sets had x-ray emissions in excess of 0.5 mR/hr; after modification, all sets emitted less than 0.5 mR/hr. A second object of the survey was to evolve and test new instruments and new methods of measurement for a future survey of television sets produced by all manufacturrs.

KEYWORDS: Color television receivers, Florida, home surveys, picture tube, radiographic films, regulator tube, x-ray emissions.

A SUMMARY OF THE WASHINGTON, D.C. METROPOLITAN AREA SURVEY OF COLOR TELEVISION RECEIVERS. *Technical Services Branch, National Center for Radiological Health.* Vol 9, October 1968, pp. 531–538.

A survey was conducted by the National Center for Radiological Health (NCRH) during December 1967 and January 1968 with the cooperation of the Electronic Industries Association and individual manufacturers to obtain x-ray emission data from color television receivers owned by Public Health Service employees in the Washington, D.C. area. Radiation measurements, using a survey instrument developed by the NCRH, were made on 1,124 color television sets of various makes and models. Of these sets, 66 emitted x rays at exposure rates in excess of the recommended level of 0.5 mR/hr. The x-rays emissions were reduced to acceptable levels through service adjustments, such as replacement of shunt regulator or rectifier tubes and reduction of the operating high voltage. The survey results are considered to be valid only for the sample of sets examined in the Washington, D.C. area.

KEYWORDS: Color television receivers, home surveys, Washington, D.C., x-ray emissions.

76

☆ U.S. GOVERNMENT PRINTING OFFICE : 1968 342-801/3

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 9, Number 11, November 1968

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

***Radiological Health Data and Reports*, a monthly publication of the Public Health Service, includes data and reports provided to the National Center for Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.**

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

Department of Defense
Department of the Interior
Department of Agriculture
Department of Commerce
Department of Health, Education, and Welfare
Atomic Energy Commission

CONTENTS

Page

REPORTS

Whole Body Cesium-137 and its Relation to Body Composition and Diet 619
R. C. Steinkamp, T. W. Sargent, E. Isaacs, N. L. Cohen, E. M. Hutson, and *N. D. Kunkel*

TECHNICAL NOTES

Personnel Monitoring of Radiologists during Fluoroscopy .. 627
S. C. Bushong, T. S. Harle, M. Pogonowska and *J. A. Burdine*

DATA

SECTION I. MILK AND FOOD 631
National and International Milk Surveillance 632
  1. Pasteurized Milk Network, July 1968, *PHS* 632
  2. Canadian Milk Network, July 1968 635
  3. Pan American Milk Sampling Program, July 1968 *PAHO* and *PHS* 636
State Milk Surveillance Activities 637
  1. California Milk Network, April-July 1968 637
  2. Colorado Milk Network, July 1968 639
  3. Connecticut Milk Network, April-July 1968 640
  4. Florida Milk Network, July 1968 641
  5. Indiana Milk Network, April-July 1968 642
  6. Iowa Milk Network, April-July 1968 643
  7. Michigan Milk Network, April-July 1968 645
  8. Minnesota Milk Network, April-July 1968 647
  9. New York Milk Network, April-July 1968 649
  10. Oregon Milk Network, April-July 1968 651
  11. Pennsylvania Milk Network, April-July 1968 652
  12. Tennessee Milk Network, July 1968 653
  13. Texas Milk Network, July 1968 654
  14. Washington Milk Network, April-July 1968 655

CONTENTS—continued

Page

Food and Diet Surveillance 657

1. Estimated Daily Intake of Radionuclides in Connecticut Standard Diet, January-June 1968 657

SECTION II. WATER 659

Gross Radioactivity, May 1968, and Strontium-90, July 1966-September 1967, in Surface Water of the United States, *FWPCA* 660

Tritium in Surface Water Network, January-June 1968 665

Radioactivity in California Waters, July-December 1967 667

Radioactivity in Kansas Surface Waters, July-December 1967 671

SECTION III. AIR AND DEPOSITION 673

1. Radiation Alert Network, July 1968, *PHS* 674
2. Canadian Air and Precipitation Monitoring Program, July 1968 677
3. Pan American Air Sampling Program, July 1968 *PAHO* and *PHS* 678

SECTION IV. OTHER DATA 679

Field Measurements of Natural Background Gamma Radiation using Calibrated Portable Scintillation Counter, *NCRH* 679

Iodine-131 in Bovine Thyroids, April-June 1968 *PHS* 695

Radionuclides in Washington Shellfish, July 1964 through December 1967 697

Environmental Levels of Radioactivity at Atomic Energy Commission Installations 701

1. Los Alamos Scientific Laboratory, Calendar year 1967 701
2. Rocky Flats Plant, January-June 1968 702

Reported Nuclear Detonations, October 1968 704

Synopses iii

Guide for Authors .... Inside back cover

RADIOLOGICAL HEALTH DATA AND REPORTS

Published under the direction of

James G. Terrill, Jr., Director and
Dr. Raymond T. Moore, Deputy Director
National Center for Radiological Health

by the Standards and Intelligence Branch
Donald L. Snow, Chief

BOARD OF EDITORIAL ADVISORS

Dr. Harold O. Wyckoff
Department of Defense

Milton W. Lammering
Department of the Interior

Dr. Ronald G. Menzel
Department of Agriculture

Reuben Pomerantz
Department of Commerce

Robert E. Simpson
Food & Drug Administration, DHEW

John A. Harris
Atomic Energy Commission

STAFF

Managing Editor
Samuel Wieder

Assistant Managing Editor
Kurt L. Feldmann

Senior Technical Editor
Marvin Rosenstein

Technical Editors
Warren A. Brill
William H. Oates, Jr.

Address correspondence to the Managing Editor, *Radiological Health Data and Reports*, National Center for Radiological Health, 12720 Twinbrook Parkway, Rockville, Md. 20852.

For subscriptions to *Radiological Health Data and Reports*, please use the order form on last page of this issue.

CONSUMER PROTECTION AND ENVIRONMENTAL HEALTH SERVICE
Environmental Control Administration • National Center for Radiological Health

78

Reports

Whole Body Cesium-137 and its Relation to Body Composition and Diet

R. C. Steinkamp, T. W. Sargent, E. Isaacs, N. L. Cohen, E. M. Hutson, and *N. D. Kunkel*[1]

Between September 1962 and July 1963, a time of rising cesium-137 content in the biosphere, whole body cesium-137 and potassium-40 measurements were performed in an Argonne-type scintillation counter on 80 subjects; 52 men and 28 women. These data have been correlated with body composition estimates of body fat and lean body mass. Seventy-eight of the subjects had diet interviews. The intakes of food categories were correlated with *in vivo* cesium-137 measurements. The results suggest that calculations of dose rates for cesium-137 may be more meaningful if based on lean body mass rather than total body weight, as is done presently.

Intakes of milk and fruits and vegetables correlated significantly with *in vivo* cesium-137 measurements for those subjects with extremely low or extremely high food intakes. A regression equation was determined to calculate pCi cesium-137/g potassium in people from pCi cesium-137/g potassium in milk. There appeared to be a time lag of 4 to 5 months between rising values of cesium-137 in milk and those in people, consistent with the biological half-life of cesium-137.

Since the first detection of cesium-137 in human subjects in 1956, this long-lived nuclear fission product has received considerable attention (*1*). The contribution of cesium-137 to the total body burden of radioactivity, the mechanisms of entry into the biosphere, and the metabolic fate in men and experimental animals have been studied since 1956.

Cesium-137 has been assumed to be distributed uniformly throughout the body for dose-rate calculations in man (*2, 3*). The present study, performed during a time of increasing cesium-137 body burdens, presents cesium-137 measurements in relation to body composition and potassium measurements as well as food intake. Ingestion of either low or high amounts of milk as well as of fruits and vegetables have been related to cesium-137 body burdens.

Materials and methods

A detailed description of the subjects and methods has been published previously (*4*). The subjects of this study were 80 healthy San Francisco Bay Area residents between the ages of 25 and 44 years. Fifty-two men (49 Caucasian and 3 Negro) and 28 Caucasian women were studied between September 1962 and July 1963.

Cesium-137 and potassium were measured in an Argonne-type whole body scintillation counter (*5*). Suitable precautions were used to avoid external contamination. The mean counting efficiency for cesium-137 was 8.1 counts per minute (cpm) per nCi in a 180 keV band at the photopeak, with a standard deviation of 0.96 cpm/nCi (*6*). For potassium, an average counting efficiency of 1.09 ± 0.10 cpm/g potassium in a 300 keV band at the photopeak, with a standard deviation of 9.7 percent was determined by calibration with potassium–42 injected into normal volunteers.

---

[1] Dr. Steinkamp is medical consultant, Bureau of Public Health Nutrition, California State Department of Public Health, Berkeley, Calif.; Dr. Sargent is staff biophysicist, Donner Laboratory, University of California; Mrs. Isaacs was formerly research assistant, Donner Laboratory, University of California; Dr. Cohen was formerly associate public health statistician, Bureau of Public Health Nutrition; Mrs. Hutson was formerly research nutritionist, Bureau of Public Health Nutrition; and Mrs. Kunkel is research nutritionist, Bureau of Public Health Nutrition, California State Department of Public Health, Berkeley, Calif.

The dose rate for cesium–137 was calculated by using the formula (*3*):

$$D = 11 \frac{\text{cesium–137 in nCi}}{\text{body weight in kg}} \text{ mrem/year,}$$

where 11 is the dose conversion factor based on the absorption of 0.59 MeV per disintegration.

Body fat was estimated for each subject from four anthropometric measurements according to a linear regression equation appropriate for his age, race and sex (*7*). Lean body mass was calculated by subtracting estimated body fat in kilograms from the subject's total body weight in kilograms.

Twenty-four hour diet recall records were obtained for all subjects except two of the men who were measured for radioactivity in January and February 1963. Methods for diet recall (*4*) and results of nutrient calculation (*9*) have been previously reported. For this report, the diet interviews were reevaluated to obtain quantities consumed for five food categories. These were milk, milk plus all other dairy products calculated in milk equivalents[2], cereals, animal protein foods (including lean meats of all types, fish and eggs), and fruits and vegetables. All food categories were calculated in ounces consumed except for the cereals group, which was scored in number of servings[3].

Body composition and total body cesium–137

Table 1 presents means and standard deviations for body composition, cesium–137 measurements and total body potassium. Mean percent body weight as fat estimated from the anthropometric measurements compares favorably with that calculated from total body water and body density measurements (*4, 7, 9*) for a larger group of subjects (table 2). Estimates of lean body mass by anthropometric methods compare favorably with those obtained by the laboratory procedures.

Table 1. Average body composition cesium–137 and potassium values for adults 25 to 44 years old

Parameter measured	Men (n = 52)		Women (n = 28)	
	Mean	S.D.	Mean	S.D.
Body weight (kilograms)	77.97	12.37	62.17	13.33
Lean body mass (kilograms)	58.61	7.93	41.44	7.44
Body weight as fat (percent)	24.3	6.38	32.8	5.08
Cesium-137 (nCi)	7.4	2.25	5.3	2.17
Potassium (grams)	137	16.7	91	8.25
Cesium-137/potassium (pCi/g K)	53.9	12.9	57.8	20.0
Dose rate of cesium-137 (mrem/yr)	1.06	0.35	0.96	0.39

Table 2. Percent body weight as fat for adults 25 to 44 years old

Category of subjects	Number of subjects	Mean percent body weight as fat
Caucasian men, 25-34 yrs.	35	22.0
Caucasian men, 35-44 yrs.	34	26.8
Caucasian women, 25-34 yrs.	33	30.7
Caucasian women, 35-44 yrs.	31	35.8
Negro men, 25-44 yrs.	34	22.5

On the basis of determinations of 311 people from 30 States, Anderson calculated total potassium values of 139 grams (standard deviation = 19 percent) for a "standard" man weighing 70 kg (*10*). Our determinations yield a value of 123 grams potassium for a 70 kg man.

Mean cesium–137/potassium ratios were slightly greater and total dose rates were slightly lower for women than for men, reflecting the lower levels of potassium, lean body mass, and total body weight for women. Mean values of cesium–137/potassium for people in the United States were reported as 69 pCi/g for fiscal year 1959, and 28 pCi/g for the first quarter of 1962 by the Walter Reed Institute of Pathology (*11*). In England, Rundo and Newton (*12*) found values ranging from 50 to 90 pCi cesium–137/g of potassium and average total cesium–137 values of 7.0 to 12.6 nCi between October 1962 and July 1963 (comparable to the time period and the results of the present study).

---

[2] Milk equivalents were taken from *Conversion Factors and Weights and Measures for Agricultural Commodities and Their Products*. Production and Marketing Administration of the U.S. Department of Agriculture, May 1952, and are: 1 ounce hard cheese = 10 oz. milk; 1 ounce cottage cheese = 6 oz. milk; ½ cup ice cream = 8 oz. milk.

[3] Each of the following was considered as one serving of cereal: 1 slice bread; ½ cup cereal, either cooked or dry; 2 cookies; 3 ounces cake.

Table 3 presents correlation coefficients, "r" for cesium–137 content with estimated body composition and potassium measurements for all subjects by sex based on the consideration of variables from a bivariate normal distribution. Total cesium–137 values were significantly correlated with potassium measurements for both men and women. It is interesting that for the women, correlation of cesium–137 with lean body mass was greater than with total body weight, as was the case for men.

Table 3. Correlation of cesium–137 content (nCi) with estimated body composition and potassium measurements—all subjects

Parameter measured	Men (n=52) r value	Men (n=52) P	Women (n=28) r value	Women (n=28) P
Body weight (kilograms)	0.324	<0.02	0.082	NS
Lean body mass (kilograms)	.498	<.01	.221	NS
Body weight as fat (percent)	−.211	NS	−.264	NS
Potassium (grams)	.646	<.01	.509	<0.01

NS, not significant.

Studies of mammalian tissues indicate that fat has the lowest cesium–137 concentration of any tissue studied. In dogs chronically exposed to cesium–137, Furchner and colleagues (*13*) found the ratio of cesium–137 in fat to cesium–137 in whole body was < 0.01 while the ratio cesium–137 in muscle to cesium–137 in whole body was >2.0. Concentrations in other soft tissues, except the gonads, pelt and fat approximated whole body cesium–137 concentration. The low concentrations in the gonads and pelt were related to the large amount of fat and low concentration of muscle in these organs. More recently, Baratta and Ferri (*14*) have found in human autopsy specimens that the greatest concentrations of cesium–137 was in muscle, and was about twice that in spleen and liver. Unfortunately, no data were presented for fat specimen analyses in their study.

The suggestion of Langham and Anderson (*15*) to express the concentration of cesium–137 in the body in terms of cesium–137/potassium ratio, because of the chemical similarities of cesium to potassium, has been generally accepted. Rundo (*16*), however, has pointed out differences as well as similarities between cesium and potassium metabolism in man. Whole body cesium retention has been found by Rundo (*16*) and Grundy and Sargent (*6*) to be a two-component exponential function of time. Approximately 10 percent of ingested cesium is excreted with a half-life of 1 to 2 days; the major part is excreted with a half-life of about 110 days. Rundo has attributed a larger part of the variability of cesium–137 contents among individuals to the variability in biological half-life and at the same time has recognized that dietary habits must control the cesium–137 level reached in the body.

Although atmospheric testing was resumed in September 1961, a rise in cesium–137 values has been noted only since the summer of 1962 (*17*). Since the time period during which our subjects were measured encompassed the rising trend in cesium–137 values, it is unlikely the cesium–137 body burdens of the subjects were in equilibrium with their diets. The cesium–137/potassium ratios, therefore, have been averaged by quarter years in table 4. Analysis of variance among the quarter years provided F values of 6.20 for men and 21.4 for women. The critical F values at the 1 percent level are 4.22 and 4.72, respectively.

Because of the increase of cesium–137 body burden over time and the few subjects measured during the first and last months of the study, further analysis of cesium–137 and body composition was limited to those measured between October 1962 and June 1963. There

Table 4. Cesium–137/potassium ratios for men and women living in the San Francisco Bay area by quarter year

Period	Men (cesium-137/potassium ratio, pCi/g)					Women (cesium-137/potassium ratio, pCi/g)				
	Number of subjects	Mean	S.E. of mean	Minimum	Maximum	Number of subjects	Mean	S.E. of mean	Minimum	Maximum
September 1962	4	55.80	5.62	36.52	67.43	—	—	—	—	—
October-December 1962	23	47.26	2.34	24.91	85.67	8	46.66	3.89	27.44	55.38
January-March 1963	16	56.54	2.81	43.88	87.70	9	50.37	3.67	42.86	57.56
April-June 1963	9	65.54	3.75	56.99	82.27	8	60.01	3.89	45.32	77.12
July 1963	—	—	—	—	—	3	103.77	6.31	75.11	128.80

were totals of 31, 25 and 17 subjects measured in the three quarter years. Total body cesium–137 measurements were 5.79 ± 1.80[4] nCi for October to December 1962, 6.69 ± 2.41 nCi for January to March 1963, and 7.57 ± 2.77 nCi for April to June 1963. Table 5 presents the correlation coefficients for these data with total body weight, lean body mass and potassium. As the cesium–137 contents increased with time, correlations with body composition measurements became greater. There was little difference among the groups for mean total body weight and for mean lean body mass.

Table 5. Correlation coefficients for cesium–137 measurements and for body composition by quarter year

Parameter measured	Oct-Dec 1962 (n=31)	Jan-Mar 1963 (n=25)	April-June 1963 (n=17)
Cesium-137 (nCi) and body weight (kilograms)	0.369 [*]	0.572	0.713
Cesium-137 (nCi) and lean body mass (kilograms)	.583	.768	.842
Cesium-137 (nCi) and potassium (grams)	.670	.866	.914
Body weight (kilograms) and potassium (grams)	.710	.723	.791
Lean body mass (kilograms) and potassium (grams)	.868	.943	.947

[*] $p = <0.05$. For all other values, $p = <0.01$.

Linear regressions of cesium–137 on total body weight and on lean body mass were obtained for each of the three groups by quarter year (table 6). Total body weight for the period October to December 1962 was remarkably similar to the regression obtained by Maycock et al (*3*), for 182 women and 21 men luminizers measured in Surrey between January 1958 and the end of 1959. This is not surprising since the mean cesium–137 body burden for an individual weighing 60 kg was 5.5 nCi in Maycock's study and 5.45 nCi in the present study. The similarity may be misleading, since the subjects in the former study comprised considerably more women (182) than men (21), while our subjects were 28 women and 52 men. Data presented in Maycock's report are insufficient to calculate mean cesium–137 per 60 kg body weight by sex. For our subjects, these data were 6.54 nCi for men and 5.10 nCi for women. The sex difference may in part be accounted for on the basis that fat comprised 8.5 percent more of the total body weight of women than of men. As noted in table 6, the regressions for cesium–137 on lean body mass had lower standard errors than for comparable regressions on total body weight.

Table 6. Linear regression of cesium–137 (nCi) on total body weight (kilograms) and on lean body mass (kilograms) by quarter year

Time period	Regression	S.E.
October to December 1962	0.048 TBW + 2.245	1.431
	0.095 LBM + 0.568	1.164
January to March 1963	0.081 TBW + 0.832	1.581
	0.161 LBM − 1.624	1.166
April to June 1963	0.126 TBW − 1.436	1.491
	0.174 LBM − 1.371	1.107

TBW, total body weight
LBM, lean body mass

Cesium–137 and diet

No consistent correlation for cesium–137/potassium ratios with intakes of food groups was found (table 7). Variations among intakes for each food category were great; for example, the first two groups of men had intakes of milk varying from 5 to 49 and 0 to 56 ounces per day, respectively. Intake ranges for milk for the remaining subject groups and for other food groups were generally smaller than the above two values.

Only three of our groups of subjects showed positive, as well as high correlation with milk intake. However, when the seasonal variations of cesium–137/potassium ratio as well as extremes of milk intakes were considered, highly significant differences were obtained. Deviations from seasonal mean cesium–137/potassium ratios were calculated for 17 subjects having no intake of milk and 18 subjects with milk intakes equal to or greater than 20 ounces a day. A rank sum test of the differences was made. This provided a probability of less than two times in one hundred that the differences from the seasonal mean cesium–137/potassium ratio would have occurred by chance. Rank sum tests of the differences from seasonal mean ratios were similarly performed for food group intakes for meat, cereal, fruits and vegetables. Levels of comparisons were intakes of $\leq$ 4 ounces ($n = 16$) and $\leq$ 10 ounces ($n = 14$) for meat; $\leq$ 3 servings ($n = 13$) and $\geq$ 11 servings ($n = 11$) for cereals; and

---

[4] Standard deviation for the group of cesium–137 measurements.

82

Table 7. Median intakes of food groups and correlation with cesium-137/potassium ratios by sex and quarter year

Period and sex	Number of subjects	Milk (oz)	r	Milk and dairy products (oz)	r	Cereals (serving)	r	Animal protein foods (oz)	r	Fruits and vegetables (oz)	r
Men:											
Sept 1962	4	31.5	0.98	36.5	0.97	6.0	−0.91	6.0	0.02	18.0	0.51
Oct to Dec 1962	23	12.0	.30	19.0	.16	6.7	.23	6.7	−.02	14.0	.08
Jan to March 1963	14	4.0	.29	22.0	−.02	5.2	−.24	8.0	.37	14.0	−.38
April to June 1963	9	6.0	−.66	12.2	−.18	5.5	−.09	8.0	−.12	17.0	.30
Women:											
Oct to Dec 1962	8	12.0	−.12	28.5	−.14	4.6	−.55	5.5	.33	17.5	−.11
Jan to March 1963	9	9.5	.35	18.5	.38	4.5	.37	5.8	.13	12.0	.16
April to June 1963	8	4.5	.71	15.5	.10	6.6	−.63	5.0	−.60	17.0	−.20
July 1963	3	9.0	.99	20.0	.39	4.8	−.19	7.5	.54	11.0	.37

$\leq$ 9 ounces (n = 16) and $\geq$ 24 ounces (n = 15) for fruits and vegetables. Of these, only the latter was significant at the 2 percent level but not at the 1 percent level.

Mean intakes of milk and dose rates of cesium-137 for the 78 subjects having diet interviews have been plotted in figure 1 together with the mean cesium-137 content of milk from the San Francisco Bay area (*18*) by month. The few subjects studied during the first and last months precluded statistical evaluation; however, the described trends for cesium-137 content of milk and of subjects were consistent for these groups.

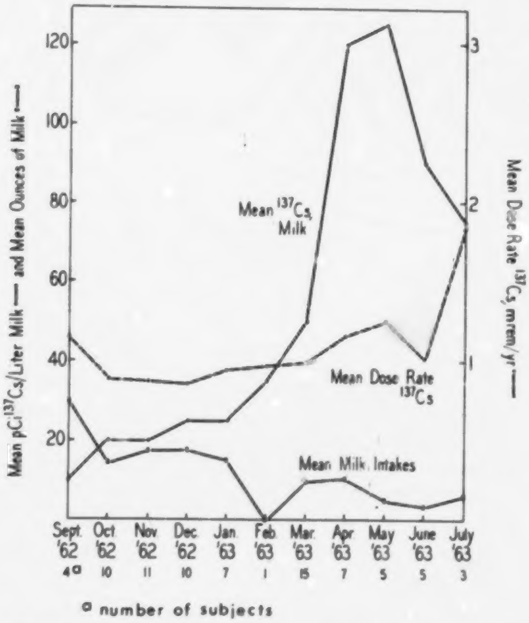

Figure 1. Cesium-137 in milk from San Francisco Bay area, mean milk intakes, and mean cesium-137 dose rates for 78 Bay area subjects

A correlation between milk intake and cesium-137/potassium in the body has been found by Rundo (*19*) and by Anderson (*10*). Milk intake was considered responsible for about one-half of the average cesium-137 body burden for the nine subjects studied by Rundo in late 1958 and early 1959. The mean content was 51 pCi cesium-137/g potassium with about 25 pCi cesium-137/g potassium derived from food other than milk. In 1957, Anderson (*10*) observed average cesium-137 levels of 44 pCi/g potassium for people in different regions of the United States. Plotting these levels against cesium/potassium ratios in milk by regions, Anderson deduced that 23 pCi cesium-137/grams potassium was derived from food sources other than milk. Figure 2 presents similar analysis of our data. The conversion factor of 1.44 g potassium per liter milk was used[5]. The slope of the interrupted line, which did not employ the limited data for September 1962 and July 1963, has an intercept at 44 pCi cesium-137/g potassium. Following Anderson's reasoning, this amount can be considered the portion of cesium-137 derived from foods other than milk. Since the mean cesium-137/potassium ratio for subjects measured from October 1962 through June 1963 was 54 pCi, only about one-fifth of the cesium-137 body burden can be considered derived from milk. The relative contribution from milk was 23 percent in 1961 (*20*). For all subjects, shown by solid line in figure 2, the slope is the same as for subjects from October through June but the variance is six-fold greater, indicative of the wide range for cesium-137 over this time period.

---

[5] Agriculture Handbook No. 8, Composition of Foods. U.S. Department of Agriculture, December 1963. Watt, B. K., and A. L. Merrill.

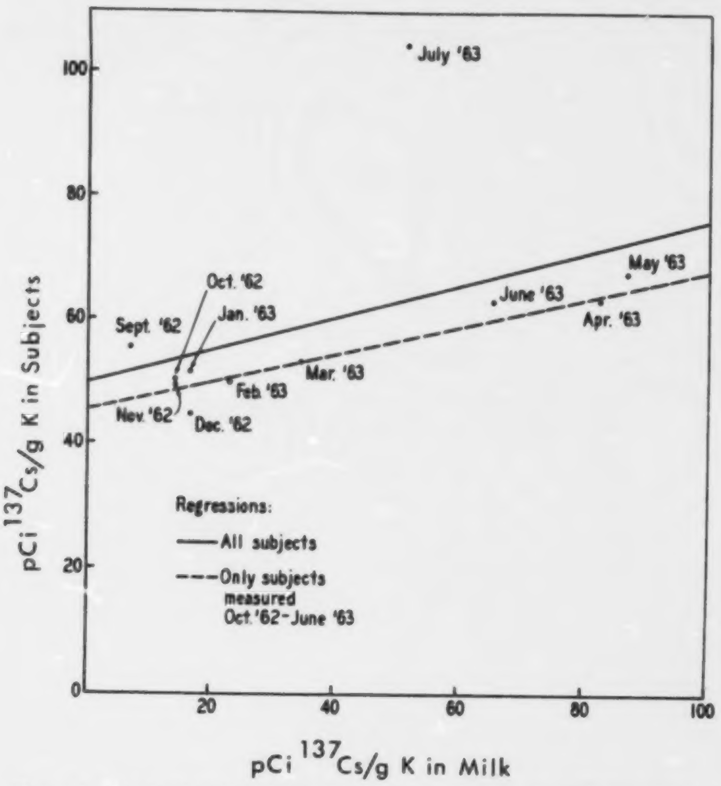

Figure 2. Levels of cesium-137 in subjects versus levels in milk by month

Total diet studies (including drinking water) for the San Franciso Bay area are analyzed at intervals for radionuclides (*21, 22*). These studies show per capita cesium-137 intakes of 3.8 pCi/day for May 1962 (*21*), 53 pCi/day for August 1962 (*21*), 34 pCi/day for November 1962 (*21*), 33 pCi/day for December 1962 (*22*), 60 pCi/day for February 1963 (*21*), and 286 pCi/day for May 1963 (*21*). These data, based on the teen-age and Tri-City Diet studies represent figures for greater quantities of food than were consumed by the subjects of this study. Unfortunately, the present monitoring system of radioactivity in California diets had not been instituted at the time of this study; this would have afforded values more comparable to diets of our subjects. Composition of diets used for analysis in the Tri-City Diet studies are available and are based on average U.S. consumption per year (*22*). Comparison of the standard diet with subject mean intakes for food groups was made (table 8).

Table 8. Comparison of Tri-City diet with diet of subjects

Food group	Tri-City diet (oz/day, average)	All subjects (oz/day, average)
Milk	21.4	12.0
Milk and milk products	—	23.4
Poultry, fish, meat, egg	11.1	7.1
Bread, flour, cereal, etc.	9.4	6.3
Fruits and vegetables	23.3	16.8

Composition of diets used for the teen-age studies are not available, but possibly represent even larger quantities of food than are analyzed in the Tri-City Diet studies. The above analyses for cesium-137 are therefore somewhat in excess of quantities consumed by the average subject in this study.

An additional consideration must be recognized with respect to cesium-137 analyses of diets for the Tri-City Diet studies. Foods are prepared as for cooking, with inedible portions removed, but the foods were not actually cooked. Although little is known of the effects of food processing and cooking on the cesium-137 content of food, there is indication that canning and freezing reduce the amount of this radionuclide (*23*).

Summary

Between September 1962 and July 1963, a time of rising cesium-137 content in the biosphere, whole body cesium-137 and potassium measurements were performed in an Argonne-type scintillation counter on 80 subjects; 52 men and 28 women. These data have been correlated with body composition estimates of body fat and lean body mass. Seventy-eight of the subjects had diet interviews. The intakes of food categories (milk, milk and other dairy products, animal protein foods, cereals, and fruits and vegetables) were correlated with *in vivo* cesium-137 measurements.

The results indicate whole body cesium-137 content correlates better with lean body mass than with total body weight. This is consistent with animal studies in which little cesium-137 has been found deposited in fat and with human autopsy specimens in which largest quantities are deposited in muscle. These results suggest calculations of dose rates for cesium-137 may be more meaningful if based on lean body mass rather than total body weight. The importance of this may be justified on the basis that persons with proportionately little body fat and large lean body mass may receive a greater dose-rate throughout the body than persons of comparable body weight but in whom the body composition parameters are proportionately opposite.

Diet intake of milk and of fruits and vegetables correlated significantly with *in vivo* cesium-137 measurements when the extremes of food intakes were considered. A regression equation was determined to calculate pCi cesium-137/g potassium in people from pCi cesium-137/g potassium measurements in milk. There appeared to be a time lag of 4 to 5 months between rising values of cesium-137 in milk and those in people, consistent with the biological half-life of cesium-137.

Acknowledgments

Grateful appreciation is given to H. E. Walsh, chief of the Bureau of Public Health Nutrition, California State Department of Public Health, to J. H. Lawrence, M.D., director of Donner Laboratory, and to J. L. Born, M.D., associate director of Donner Laboratory, University of California, Berkeley, for their interest and support of this study; to W. R. Gaffey, Ph.D., Division of Research, California State Department of Public Health, for statistical advice, and to Mrs. P. Stephenson, assistant public health statistician, Bureau of Public Health Nutrition, California State Department of Public Health for statistical assistance.

REFERENCES

(*1*) MILLER, C. E., and L. D. MARINELLI. Gamma ray activity of contemporary man. Science 124:122–123 (July 20, 1956).

(*2*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 2. Pergamon Press, New York, N.Y. (1959).

(*3*) MAYCOCK, G., S. W. TERRY, J. VENNART, and E. M. WISE. Measurements of caesium-137 in human beings during 1958–59. Nature 188:355–357 (October 29, 1960).

(*4*) STEINKAMP, R. C., N. L. COHEN, W. E. SIRI, T. W. SARGENT, and H. E. WALSH. Measures of body fat and related factors in normal adults. I. Introduction and methodology. J Chronic Diseases 18:1279–1289 (December 1965).

(*5*) SARGENT, T. W. Metabolic studies with Fe^{59}, Ca^{47} and C^{11} in various diseases. Whole body counting, IAEA (Vienna), 1962.

(*6*) GRUNDY, R. D., and T. W. SARGENT. Whole-body counting studies using cesium-132. J Nucl Med 7:676–686 (September 1966).

(*7*) STEINKAMP, R. C., N. L. COHEN, W. R. GAFFEY, T. McKEY, G. BRON, W. E. SIRI, T. W. SARGENT, and E. ISAACS. Measures of body fat and related factors in normal adults. II. A simple clinical method to estimate body fat and lean body mass. J Chronic Diseases 18:1291–1307 (December 1965).

(*8*) SIRI, W. E. The gross composition of the body. Advances In Biological and Medical Physics, Vol. IV, 239 Academic Press, Inc. (1956).

(*9*) HUTSON, E. M., N. L. COHEN, N. D. KUNKEL, R. C. STEINKAMP, M. H. ROURKE, and H. E. WALSH. Measures of body fat and related factors in normal adults. III. Diet and physical activity. J Amer Diet Assn 47:179–186 (September 1965).

(*10*) ANDERSON, E. C. Radioactivity of people and milk: 1957. Science 128:882–886 (October 17, 1958).

(*11*) WALTER REED ARMY INSTITUTE OF RESEARCH. Geographical distribution of cesium-137 in man, July 1958 through September 1962. Radiol Health Data 4:214–215 (April 1963).

(*12*) RONDO, J., and D. NEWTON. Increases in the cesium-137 content of man due to radioactive fall-out, 1962–64. Nature 203:537–538 (August 1, 1964).

(*13*) FURCHNER, J. E., G. A. TRAFTON, and C. R. RICHMOND. Distribution of cesium-137 after chronic exposure in dogs and mice. Proc Soc Exptl Biol Med 116:375–378 (June 1964).

(*14*) BARATTA, E. J., and E. S. FERRI. Strontium-90, cesium-137, and polonium-210 in human tissues. Radiol Health Data Rep 8:298-299 (May 1967).

(*15*) LANGHAM, W. H., and E. C. ANDERSON. Cs^{137} biospheric contamination from nuclear weapons tests. Health Physics 2:30-48 (July 1959).

(*16*) RUNDO, J. The metabolism of biologically important radionuclides. VI. A survey of the metabolism of caesium in man. Brit J Radiol 37:108-114 (Feburary 1964).

(*17*) ELLETT, W. H., and G. L. BROWNELL. Caesium-137 fall-out, body burdens, time variation and frequency distribution. Nature 203:53-55 (July 4, 1964).

(*18*) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Pasteurized milk network, September 1962–July 1963. Radiol Health Data 4:23-26 (January 1963); 4:86-89 (February 1963); 4:138-142 (March 1963); 4:183-187 (April 1963); 4:233-243 (May 1963); 4:291-296 (June 1963); 4:359-363 (July 1963); 4:405-407 (August 1963); 4:455-459 (September 1963); 4:499-503 (October 1963); 4:551-557 (November 1963).

(*19*) RUNDO, J. Radiocaesium in human beings. Nature 188:703-706 (November 26, 1960).

(*20*) ANDERSON, E. C., G. M. WARD, J. Z. HOLLAND, and W. H. LANGHAM. Cesium-137 levels in United States powdered milk and in the population. Radioactive fallout from nuclear weapons tests. Proceedings of a conference, November 15-17, 1961. A. W. Klement, Jr., Editor, U.S.A.E.C. T.I.D. 7632: 477-516 (February 1962).

(*21*) FOOD AND DRUG ADMINISTRATION, DIVISION OF PHARMACOLOGY. Radionuclides in diets for teenagers, May 1962–November 1963. Radiol Health Data 5:181-183 (April 1964).

(*22*) RIVERA, J., and J. J. KELLY. Cesium-137 in Tri-City diets, October–December 1962. Radiol Health Data Rep 5:434-436 (September 1964).

(*23*) FOOD AND DRUG ADMINISTRATION, DIVISION OF PHARMACOLOGY. Cesium-137 and strontium-90 in foods. Radiol Health Data 4:81-85 (February 1963).

Personnel Monitoring of Radiologists During Fluoroscopy

Stewart C. Bushong, Thomas S. Harle, Magadalena Pogonowska and *John A. Burdine* [1]

A generally accepted observation has been that the greatest exposure to a diagnostic radiologist occurs during fluoroscopic procedures, even though he is normally wearing protective apparel during these procedures. Because the protective apparel perturbs the normal radiation field, there is some confusion and inconsistency regarding the placement of personal monitoring devices during fluoroscopy. The question arises frequently as to where is the most appropriate position on the body for a radiologist to wear his film badge.

Suggestions have been made that the film badge be worn on the belt under the protective-lead apron, at the shirt pocket level, on the upper arm, or on the head, neck or extremities (*1, 4*). The current recommendations of the National Council on Radiation Protection and Measurements are: "monitoring devices used to estimate whole body exposure normally should be worn on the chest or abdomen. When a protective apron is worn (e.g., during fluoroscopy), particular care should be taken in choosing the location of the monitoring device and in interpreting its reading" (*5*). This is a less specific recommendation than that previously made by the NCRP (*6*).

The purpose of this note is to describe data obtained from experiments designed to measure the dose equivalent to radiologists at various positions on the body.

Method of procedure

Radiologists in the Diagnostic Section of the Ben Taub General Hospital, Houston, Tex., were monitored with commercially obtained film badges at 27 positions on the body during fluoroscopy. Table 1 lists these locations.

The same badges were worn for monthly periods beginning in the middle of January 1968 by 15 radiologists and therefore the data represent an average of the factors affecting dose equivalent of different radiologists; i.e., body size and stature, individual technique, etc. Eleven of the radiologists were residents in training. During each procedure, a 0.5 mm lead equivalent apron (Gardex Company, Model 232106) was worn and a similarly constructed protective glove (Wolf Branch Company, Model 271LF) was worn on the right hand. The left hand remained ungloved (many radiologists leave the left hand ungloved for easy manipulation of spot film controls) and was normally positioned on the control panel adjacent to the viewing screen. Only the gloved right hand was used for positioning the patient. Following each procedure, the radiologist would record his identity, the type of examination and the fluoroscopy time required.

All fluoroscopic procedures were performed in one of three examination rooms, each of which contained a Model No. 11-CKF-3 x-ray machine. These machines were normally operated at 85 kVp and 3 mA and produced an exposure rate of 4.5 R/min at the tabletop under these conditions. Protective lead curtains and a Bucky slot cover were used. A

---

[1] Dr. Bushong is assistant professor of Radiophysics, Dr. Harle is associate professor of Radiology, Dr. Pogonowska is assistant professor of Radiology and Dr. Burdine is assistant professor of Nuclear Medicine; Department of Radiology, Baylor University College of Medicine.

87

Table 1. The dose equivalent of radiologists during fluoroscopy (mrem) January–April 1968

Location	First month	Second month	Third month	Total	Average (mrem/min)
Film badges:					
Control	0	0	0		
Screen panel	1,505	939	1,178	3,622	1.254
Screen panel	1,853	934	978	3,765	1.304
Forehead	60	79	76	215	.074
Front collar	163	206	322	691	.239
Front collar [a]	6	18	6	30	.010
Back collar	17	31	14	62	.022
Shirt pocket	27	28	23	78	.027
Front belt	947	1,041	1,476	3,064	1.061
Front belt [a]	12	18	24	54	.019
Right belt	604	1,184	2,306	4,094	1.418
Right belt [a]	16	19	30	65	.023
Left belt	861	1,122	1,223	3,206	1.110
Left belt [a]	21	21	29	71	.025
Back belt	23	39	30	82	.028
Right knee	178	183	110	471	.163
Right knee [a]	64	31	20	115	.040
Right foot	33	35	40	108	.027
Wrist badges:					
Gloved hand palmar	2,526	1,661	1,335	5,522	1.912
Gloved hand palmar [a]	134	274	264	672	.233
Gloved hand dorsal	1,023	1,109	727	2,859	.990
Gloved hand dorsal [a]	83	214	274	571	.198
Bare hand palmar	3,539	3,640	1,990	9,169	3.175
Bare hand dorsal	5,727	6,152	2,363	14,242	4.932
Ring badges:					
Gloved hand palmar	([b])	2,305	1,132	3,437	1.805
Gloved hand palmar [a]	222	228	318	768	.266
Gloved hand dorsal	([b])	791	1,015	1,842	.968
Gloved hand dorsal [a]	212	185	([b])	397	.200
Bare hand palmar	([b])	5,221	([b])	5,221	5.227
Bare hand dorsal	([b])	5,912	([b])	5,912	5.919

[a] Shielded by protective apron or glove.
[b] Apparent light leak, no reading.

radiation protection survey showed that exposure levels around the table were low and there was no significant difference in the radiation environment of the three rooms.

Results

The results of these measurements for three monthly monitoring periods are shown in table 1. The dose equivalent values contained in this table are the values reported by the film badge vendor who claims an accuracy of ± 10 percent. These preliminary results indicate a consistency from one period to the next over the reporting interval. Specific conclusions regarding personnel monitoring during fluoroscopy may be drawn from these results.

Table 2 is a summary of the number of examinations performed and the relative time required by each of the total 794 examinations; only one radiologist performed more than 200 examinations and only three less than 100. The number of examinations per radiologists was fairly uniform.

Discussion

The data presented in table 1 show a wide range of values. The first column indicates the location of the film badge. The next three columns show the reported dose equivalent for each badge during each monitoring period. The next column is the sum of the data from the first three monitoring periods and the last column presents the average dose equivalent per minute of fluoroscopy time as reported in table 2.

Table 2. The number of fluoroscopic examinations performed and the relative time required for each

Location	First month	Second month	Third month	Total
U.G.I. exams/avg time (min) per exam	162/4.5	147/4.6	124/4.6	433/4.58
B.E. exams/avg time (min) per exam	67/2.7	86/2.9	64/3.6	217/3.06
G.B. exams/avg time (min) per exam	31/.95	29/.83	23/.83	83/.87
Other exams/avg time (min) per exam	19/2.1	17/2.7	25/3.1	61/2.66
Total number of exams	279	279	236	794
Total time (min) recorded average	983.6	1,001.3	895.2	2,880.0
Time (min)/exam	3.53	3.59	3.79	3.63

An evaluation of personnel monitoring procedures should account for the differences in recommended maximum permissible dose equivalent (MPD) for total body exposure and extremity exposure (*7, 8*). Total body exposure includes whole body, head and trunk, active blood-forming organs, gonads, or lens of the eyes. The accumulated MPD is 5 rems multiplied by the age in years beyond age 18. Further, the quarterly MPD is 3 rem, provided the accumulated MPD has not been exceeded. The MPD for the extremities, *i.e.*, hand and forearms, feet and ankles, is 25 rem/quarter, provided the annual dose equivalent does not exceed 75 rem.

Since the film badges located on the outside of the protective apparel indicate exposure to the protective apparel and not the radiologist, they were worn for demonstration and comparison purposes only. Under no circumstances should a monitoring device be worn on the outside of protective apparel. Therefore, the subsequent discussion is primarily concerned with total body monitoring and extremity monitoring that register exposure to the radiologist and not to the protective apparel.

Of the total body monitors, the film badge positioned on the front collar received the highest exposure and the badge located on the forehead received the second highest. The exposure received by the badge worn waist level on the back was higher than that received by any of the monitors positioned waist level under the protective apron. On the basis of these data, if only a single monitor is worn, it should be worn on the front collar since this is the region of the total body which receives the most exposure.

For the extremity monitors, the exposure of badges positioned on the right foot and knee was considerably less than that of the badges positioned on the hands and wrists; consequently, as one might expect, extremity monitoring should be concerned primarily with the upper extremities. Curiously enough, the monitors on the bare left hand received a higher exposure than the monitors positioned outside of the protective glove on the right hand. The reason for this is not clear. A resurvey of the x-ray machine showed a higher than expected exposure rate at the screen control panel. This was also indicated by the two film badges positioned on the screen control panel during fluoroscopy.

In order to view these data in perspective, the recorded dose equivalents must be evaluated in terms of the MPD applicable to that region of the body. It may be that the extremity exposures represent a greater fraction of the MPD than do any total body monitors and that, if only a single monitor were available, it should be worn on an extremity. These data are summarized in table 3. It was assumed that 75 fluoroscopic examinations were performed per week, 50 weeks per year, each examination requiring 3.63 minutes. The expected annual dose equivalent at each anatomical location was calculated on the basis of the average values shown in table 1. The MPD's used were 5 rem for total body and 75 rem for extremities.

The data presented in table 3 show that the bare hand required the highest fraction of the applicable MPD. They also show that the dose equivalent to the various other regions of the body, in relation to the applicable MPD, varies considerably. Therefore, regardless of where a film badge is worn, its position on the wearer's body should be a part of the personal monitoring record in order for that record to be interpreted meaningfully.

Table 3. The percent of maximum permissible dose equivalent at several anatomical regions

Location	(mrem/min)	(mrem/yr) [a]	Percent MPD
Bare finger dorsal	5.912	80,400	107
Bare wrist dorsal	4.932	67,100	90
Front collar	0.239	3,260	65
Forehead	.074	1,010	20
Shirt pocket [b]	.027	368	7.4
Left belt [b]	.025	335	6.7
Right belt [b]	.023	306	6.1
Front belt [b]	.019	255	5.1
Gloved finger palmar [b]	.266	3,510	4.7
Gloved wrist palmar [b]	.233	3,170	4.2

[a] Assuming 75 exam/week, 50 weeks/yr, 3.63 min/exam.
[b] Shielded by protective apron or glove.

There are few data in the literature with which to compare our results. Cowing and Spalding conducted radiation protection surveys on fluoroscopic installations in order to determine the minimum safe room size for this type of facility (*9*). They estimated an average exposure at the waist level of 11.4 mR/

exam and 4.77 mR/exam outside and inside the protective lead apron, respectively. The values obtained in our study were 4.24 mR/exam and 0.075 mR/exam outside and inside the apron, respectively. Jacobson, et al. performed an investigation of exposures to radiologists during fluoroscopy by positioning ionization-type pocket dosimeters on various body regions (*3*). They reported that the highest exposure was to the upper arm and that that was the desired location for a monitoring device. They further reported that film badges worn on the collar are often protected from direct radiation by the fluoroscopic screen and consequently this was not an appropriate place for a personnel monitoring device. Exposures to the upper arm were not investigated in the present study and direct comparisons cannot be made.

Conclusions

On the basis of these data, radiologists and technologists should wear a film badge on their collar outside of the protective lead apron during fluoroscopic examinations. Radiologists should glove both hands, but for radiologists who will not glove both hands, the ungloved hand should be monitored. Finger rings would be more desirable, but they are less reliable. For those installations that have thermoluminescence capabilities, its possible use for hand and wrist monitoring is suggested.

Representative products and manufacturers are named for identification only, and listing does not imply endorsement by the Public Health Service and the U.S. Department of Health, Education, and Welfare.

REFERENCES

(*1*) Radiography a tool of medical science. General Aniline and Film Corporation (1965) p. 35.

(*2*) JONES, B. E. The role of the film badge in personnel monitoring. Amer Occup Hyg 4:104–112 (1961).

(*3*) JACOBSON, L. E., J. J. SCHARTZMAN, and S. HEISER. Monitoring of a diagnostic x-ray department. Radiology 58:568–582 (1952).

(*4*) JONES, B. E. The interpretation of film badge readings. Phys Med Biol 7:439–444 (1963).

(*5*) NATIONAL COMMITTEE ON RADIOLOGICAL PROTECTION AND MEASUREMENTS. Medical x-ray and gamma-ray protection for energies up to 10 MeV. NCRP Report No. 33 (February 1968).

(*6*) NATIONAL COMMITTEE ON RADIATION PROTECTION AND MEASUREMENTS. Medical x-ray protection up to three million volts, NCRP Report No. 26. National Bureau of Standards Handbook 76 (February 1961).

(*7*) NATIONAL COMMITTEE ON RADIATION PROTECTION AND MEASUREMENTS. Permissible dose from external sources of ionizing radiation, NCRP Report No. 17. National Bureau of Standards Handbook 59 Addendum (April 1958).

(*8*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).

(*9*) COWING, R. F., and C. K. SPALDING. A survey of scattered radiation from fluoroscopic units in fifteen institutions. Radiology 53:569–574 (1949).

Data

SECTION I. MILK AND FOOD

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Federal and State agencies are involved in efforts to monitor continuously the dietary intake of radionuclides. The most direct measure of radionuclide intake would be obtained through radioanalysis of the total diet. Difficulties in obtaining specific dietary data impede this approach. An alternate method entails the use of indicator foods to arrive at an estimate of the total dietary radionuclide intake.

Fresh milk is one such indicator food. It is consumed by a large segment of the U.S. population and contains most of the biologically significant radionuclides which appear in the diet. It also is one of the major sources of dietary intake for the short-lived radionuclides. For these reasons, fresh milk is the single food item most often used in estimating the intake of selected radionuclides by the general population and/or specific population groups. In the absence of specific dietary information, it is possible to approximate the total daily dietary intake of selected radionuclides as being equivalent to the intake represented by the consumption of 1 liter of fresh milk.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG's) for controlling normal peacetime nuclear operations, assuming continuous exposure from intake by the population at large (*1–3*). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; they do provide an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission on Radiological Protection (*5, 6*).

Data from selected national, international, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

REFERENCES

(*1*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).

(*2*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action for stronium–89, strontium–90, and cesium–137, Report No. 7. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1965).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 5. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (July 1964).

(*5*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 2. Pergamon Press, New York, N.Y. (1959).

(*6*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendation of the International Commission on Radiological Protection, Report No. 6. Pergamon Press, New York, N.Y. (1964).

National and International Milk Surveillance

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various national and international organizations routinely monitor radionuclide levels in milk.

In addition to those programs reported below, *Radiological Health Data and Reports* coverage includes:

Program	Period reported	Last presented
Radiostrontium in milk, HASL	January-December 1967	August 1968

1. Pasteurized Milk Network
July 1968

National Center for Radiological Health and
National Center for Urban and
Industrial Health, PHS

The Public Health Service's Pasteurized Milk Network (PMN) is designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling of major milk production and consumption areas. The present network of 63 stations (figure 1) provides data on milk in every State, Washington, D.C., the Canal Zone, and Puerto Rico. The most recent description of the sampling and analytical procedures employed by the PMN appeared in the January 1968 issue of *Radiological Health Data and Reports* (*1*). Reference should also be made to the February 1968 issue (*2*), in which several changes in the interpretation and reporting of data were introduced.

Table 1. Analytical errors associated with determinations of radionuclide concentrations in a milk sample

Nuclide	Concentration (pCi/liter)	Error [a] (pCi/liter)	Concentration (pCi/liter)	Error [a] (percent of concentration)
Strontium-89	<50	5	≥50	10
Strontium-90	<20	2	≥20	10
Iodine-131	<100	10	≥100	10
Cesium-137	<100	10	≥100	10
Barium-140	<100	10	≥100	10

[a] Two standard deviations.

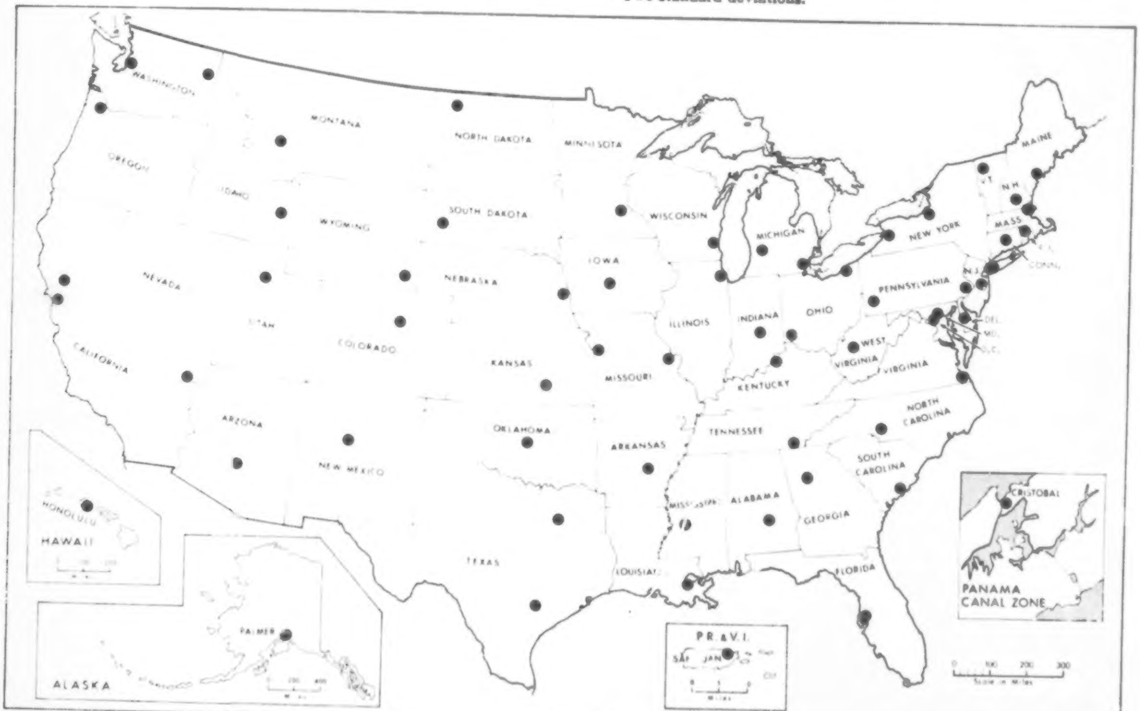
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
OREGON
IDAHO
WYOMING
SOUTH DAKOTA
WISCONSIN
MICHIGAN
NEW YORK
MAINE
VT
NH
MASS
CONN
NEVADA
NEBRASKA
IOWA
PENNSYLVANIA
N.J.
UTAH
COLORADO
ILLINOIS
INDIANA
OHIO
DEL
MD
D.C.
CALIFORNIA
KANSAS
MISSOURI
WEST VIRGINIA
VIRGINIA
KENTUCKY
ARIZONA
NEW MEXICO
OKLAHOMA
ARKANSAS
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
HONOLULU
HAWAII
MISSISSIPPI
ALABAMA
GEORGIA
TEXAS
LOUISIANA
FLORIDA
CRISTOBAL
PANAMA CANAL ZONE
PALMER
ALASKA
P.R. & V.I.
SAN JUAN
0 100 200 300
Scale in Miles

Figure 1. Pasteurized Milk Network sampling stations

Table 2. Average concentrations of radionuclides in milk for July 1968 and the 12-month period, August 1967 through July 1968

Sample location		Radionuclide concentration [a] (pCi/liter)									
		Strontium-89		Strontium-90		Iodine-131		Cesium-137		Barium-140	
		Aug 1967-July 1968	July 1968	Aug 1967-July 1968	July 1968	Aug 1967-July 1968	July 1968	Aug 1967-July 1968	July 1968	Aug 1967-July 1968	July 1968
Ala:	Montgomery	0	0	9	10	0	0	14	15	0	0
Alaska:	Palmer	0	0	5	8	0	0	15	13	1	0
Ariz:	Phoenix	0	0	1	0	0	0	2	2	0	0
Ark:	Little Rock	1	0	21	23	0	0	19	21	0	0
Calif:	Sacramento	0	0	3	0	0	0	5	2	1	0
	San Francisco	1	0	2	2	0	0	5	12	1	3
C. Z:	Cristobal	0	0	1	0	1	0	9	7	0	0
Colo:	Denver	1	0	4	4	0	0	6	13	0	0
Conn:	Hartford	NA	NA	10	14	0	0	12	15	0	0
Del:	Wilmington	NA	NA	11	12	0	0	8	9	0	0
D. C:	Washington	0	0	10	12	0	0	6	15	0	0
Fla:	Tampa	0	0	8	5	0	0	68	62	0	0
Ga:	Atlanta	0	0	14	14	0	0	20	20	0	0
Hawaii:	Honolulu	0	0	3	2	1	0	5	3	0	0
Idaho:	Idaho Falls	1	0	6	7	0	0	8	18	1	3
Ill:	Chicago	0	0	9	9	0	0	10	16	0	0
Ind:	Indianapolis	NA	NA	7	12	0	0	7	7	0	0
Iowa:	Des Moines	0	0	7	7	0	0	6	4	0	0
Kans:	Wichita	1	0	9	7	0	0	5	10	1	2
Ky:	Louisville	0	0	12	12	0	0	6	11	0	0
La:	New Orleans	0	0	22	21	0	0	24	29	0	0
Maine:	Portland	NA	NA	11	16	0	0	30	35	0	0
Md:	Baltimore	0	0	10	12	0	0	5	11	0	0
Mass:	Boston	0	0	12	17	0	0	25	38	0	0
Mich:	Detroit	NA	NA	9	14	0	0	12	12	0	0
	Grand Rapids	NA	NA	10	10	0	0	15	18	0	0
Minn:	Minneapolis	1	0	11	17	0	0	13	24	1	2
Miss:	Jackson	0	0	17	21	0	0	15	19	0	0
Mo:	Kansas City	2	6	8	5	0	0	4	3	1	0
	St. Louis	0	0	9	12	0	0	8	12	1	2
Mont:	Helena	0	0	5	6	0	0	8	15	1	2
Nebr:	Omaha	1	0	7	8	0	0	5	5	0	0
Nev:	Las Vegas	0	0	2	0	0	0	4	2	0	0
N. H:	Manchester	NA	NA	13	22	0	0	35	59	0	0
N. J:	Trenton	NA	NA	10	12	0	0	10	17	0	0
N. Mex:	Albuquerque	0	0	2	4	0	0	3	2	1	3
N. Y:	Buffalo	NA	NA	9	10	0	0	11	13	0	0
	New York city	NA	NA	11	18	0	0	14	21	0	0
	Syracuse [b]	NA	NA	7	12	0	0	8	4	0	0
N. C:	Charlotte	0	0	15	10	1	0	12	16	0	0
N. Dak:	Minot	3	7	11	11	0	0	11	12	0	0
Ohio:	Cincinnati	NA	NA	9	11	0	0	6	3	0	0
	Cleveland	NA	NA	10	14	0	0	9	12	0	0
Okla:	Oklahoma City	0	0	10	7	0	0	4	2	0	0
Ore:	Portland	1	0	7	11	0	0	15	19	1	0
Pa:	Philadelphia	NA	NA	9	14	0	0	8	16	0	0
	Pittsburg	NA	NA	12	18	0	0	14	20	0	0
P. R:	San Juan	0	0	4	4	0	0	11	8	0	0
R. I:	Providence	NA	NA	11	16	0	0	18	29	0	0
S. C:	Charleston	0	0	14	15	0	0	28	22	0	0
S. Dak:	Rapid City	1	0	10	8	0	0	10	17	0	0
Tenn:	Chattanooga	0	0	14	15	0	0	13	16	0	0
	Memphis	0	0	12	12	0	0	5	3	0	0
Tex:	Austin	0	0	4	3	0	0	3	0	0	0
	Dallas	0	0	7	9	0	0	6	8	0	0
Utah:	Salt Lake City	0	0	5	6	0	0	11	9	0	0
Va:	Norfolk	0	0	11	12	0	0	9	12	0	0
Vt:	Burlington	NA	NA	11	11	0	0	11	20	0	0
Wash:	Seattle	1	0	9	7	0	0	22	25	1	0
	Spokane	1	0	7	8	0	0	12	10	0	0
W. Va:	Charleston	0	0	12	14	0	0	4	2	0	0
Wisc:	Milwaukee	NA	NA	8	8	0	0	11	16	0	0
Wyo:	Laramie	0	0	4	4	0	0	7	15	0	0
Network monthly average		0	0	9	10	0	0	12	14	0	0

[a] See text for averaging procedure.
[b] 12-month average represents only 9 months data.
NA, no analysis.

Table 1 shows the approximate analytical errors (including counting error) associated with determinations of radionuclide concentration in milk. These errors were determined by comparing results of a large number of replicate analyses. Table 2 contains averages

93

for July 1968 and 12-month averages for the period, August 1967 through July 1968. The 12-month averages facilitate evaluations of population exposure with respect to the guidance provided by the Federal Radiation Council, which suggests average total daily intakes "averaged over periods of the order of a year," as an appropriate criterion (*3*). The average radionuclide concentrations are based on results obtained from samples collected weekly. Whenever weekly concentrations were less than or equal to the appropriate minimum detectable levels, zero was used for averaging purposes (*2*). At very low radionuclide concentrations this often results in averages lower than the minimum detectable concentration for a single sample, but any positive value reflects at least one weekly sample which was above the minimum detectable level. The minimum detectable concentration is defined as the measured concentration equal to the two-standard deviation analytical error. Accordingly, the minimum detectable concentrations in units of pCi/liter are: strontium-89, 5; strontium-90, 2; iodine-131, cesium-137, and barium-140, 10.

The average strontium-90 concentrations in pasteurized milk from selected cities are presented in figure 2.

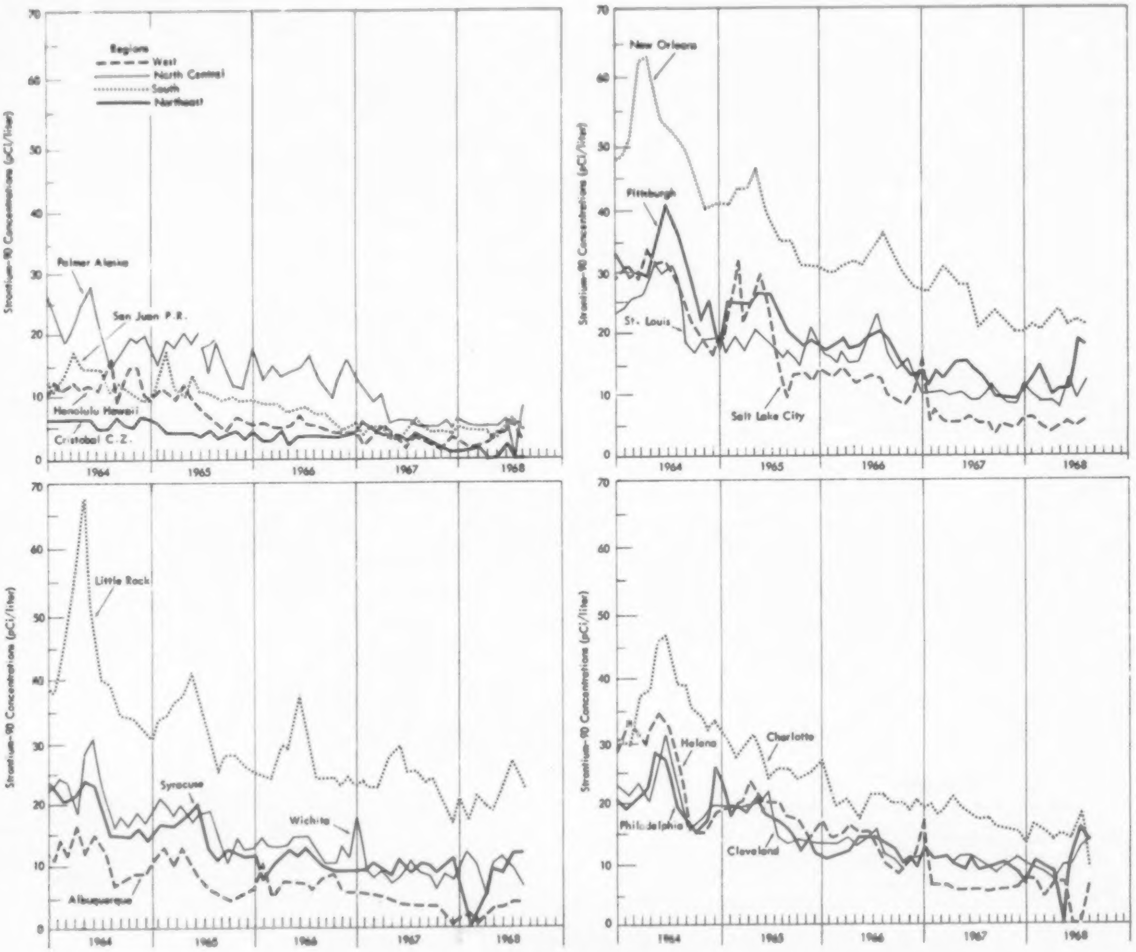

Figure 2. Strontium-90 concentrations in pasteurized milk, 1964–July 1968

2. Canadian Milk Network[1]
July 1968

Radiation Protection Division
Department of National Health and Welfare

Since November 1955, the Radiation Protection Division of the Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine–131, and monthly composites are analyzed for strontium–90, cesium–137, and stable calcium and potassium. The analytical procedures were outlined in the April 1968 issue of *Radiological Health Data and Reports* (*4*).

The July 1968 monthly average stronium–90, cesium–137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 3. Iodine–131 and stronium–89 concentrations were below minimum detectable levels.

Table 3. Stable elements and radionuclides in Canadian whole milk,[a] July 1968

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.14	1.4	8	20
Edmonton	1.10	1.5	8	23
Ft. William	1.10	1.5	20	37
Fredericton	1.06	1.6	18	31
Halifax	1.12	1.4	14	30
Montreal	1.07	1.4	10	23
Ottawa	1.12	1.4	10	23
Quebec	1.04	1.4	11	29
Regina	1.21	1.3	8	16
St. John's, Nfld.	1.12	1.5	34	60
Saskatoon	1.10	1.6	8	28
Saulte Ste. Marie	1.07	1.5	9	37
Toronto	1.10	1.5	4	15
Vancouver	1.12	1.4	16	52
Windsor	1.12	1.5	5	10
Winnipeg	1.12	1.6	10	21
Average	1.11	1.5	12	28

[a] Due to insignificant levels of strontium-89 the reporting of this radionuclide has been discontinued.

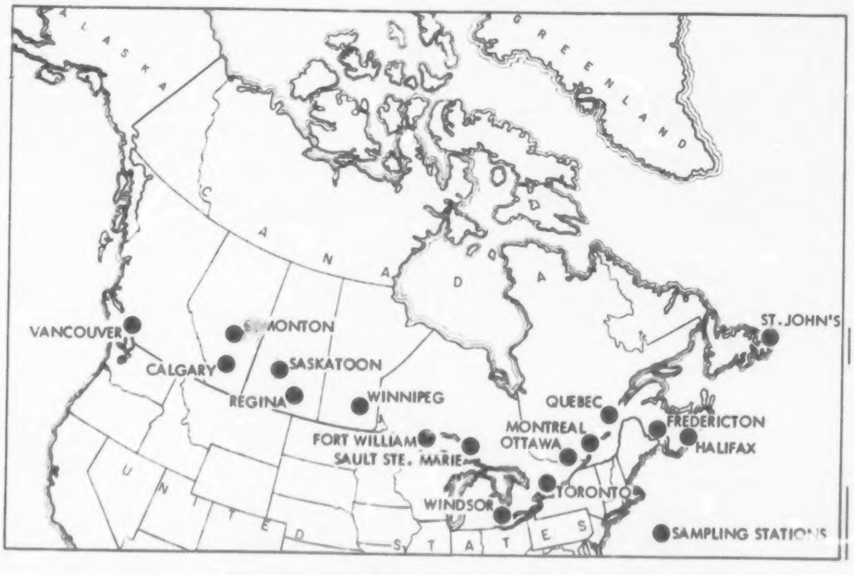

Figure 3. Canadian milk sampling stations

---

[1] Prepared from August 1968 monthly report, "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

3. Pan American Milk Sampling Program July 1968

Pan American Health Organization and
U.S. Public Health Service

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American republics engaged in developing national radiological health programs.

Under a joint agreement between agencies, milk sampling activities are conducted by a number of PAHO-member countries (figure 4). The milk sampling program was begun in August 1963, with a sampling station in Caracas, Venzuela. Between April 1964 and August 1964, stations were added in Jamaica at Kingston, Montego Bay, and Mandeville, and in the period, July to September 1966, Ecuador, Columbia, and Chile joined the program with stations at Guayaquil, Bogata, and Santiago, respectively.

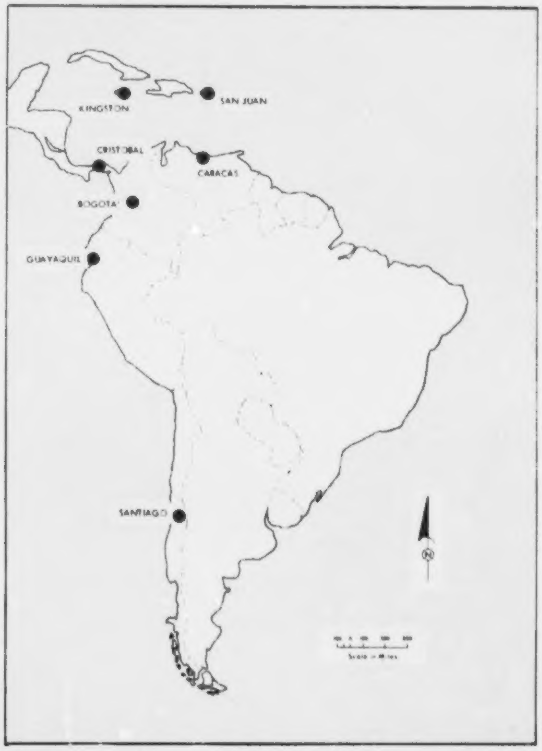

Figure 4. Pan American Milk Sampling Program locations

Sampling procedures

Sampling frequency varies according to local procedures. Collected samples are preserved with formaldehyde, composited monthly and sent to the PHS Southeastern Radiological Health Laboratory for analysis. In the case of Jamaica, the monthly composite is collected on a rotating basis from one of the three principal milk areas: Montego Bay (Montpelier), Mandeville, or Kingston (Spanish Town).

Analytical procedures

Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma scintillation spectrometry. Strontium–89 and strontium–90 are determined radiochemically. Analytical errors are discussed under "Pasteurized Milk Network, September 1967" in the January 1968 issue of *Radiological Health Data and Reports*.

Data presentation

Table 4 presents stable potassium, strontium–90, and cesium–137 monthly concentrations for July 1968.

Table 4. Stable element and radionuclide concentrations in Pan American milk,[a] July 1968

Sampling station	Number of samples	Potassium (g/liter)	Strontium-90 [b] (pCi/liter)	Cesium-137 [b] (pCi/liter)
Chile: Santiago	1	1.5	0	0
Ecuador: Guayaquil	1	1.3	0	0
Jamaica: Kingston	1	1.5	6	65
Venezuela: Caracas	1	1.6	3	0
Canal Zone: Cristobal [c]	5	1.5	0	7
Puerto Rico: San Juan	5	1.6	4	8

[a] All strontium-89 results were ≤ 5 pCi/liter; iodine-131 and barium-140 results were all ≤ 10 pCi/liter.

[b] Strontium-90 single sample results ≤ 2 pCi/liter and cesium-137 single sample results ≤ 10 pCi/liter are reported as 0.

[c] For comparison, the average radionuclide concentrations in Pasteurized Milk Network samples collected at Cristobal, Canal Zone, andSan Juan, Puerto Rico, are presented.

REFERENCES

(*1*) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, September 1967. Radiol Health Data Rep 9:20–23 (January 1968).
(*2*) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, October 1967. Radiol Health Data Rep 9:86–89 (February 1968).
(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1960).
(*4*) DEPARTMENT OF NATIONAL HEALTH AND WELFARE, RADIATION PROTECTION DIVISION. Canadian milk network, August 1966. Radiol Health Data Rep 7:702–703 (December 1966).

State Milk Surveillance Activities

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States now have comprehensive environmental surveillance programs and self-sustaining radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes. The results presented herein are representative of current surveillance activities directed at the use of milk as an indicator of dietary intake of radioactivity.

Figure 1 shows the States which report milk surveillance activities in *Radiological Health Data and Reports.* Data from these State activities have been updated through July 1968. Commencing with the December 1968 issue of *Radiological Health Data and Reports,* milk surveillance data will be reported on a monthly basis for all State, Federal, and International programs.

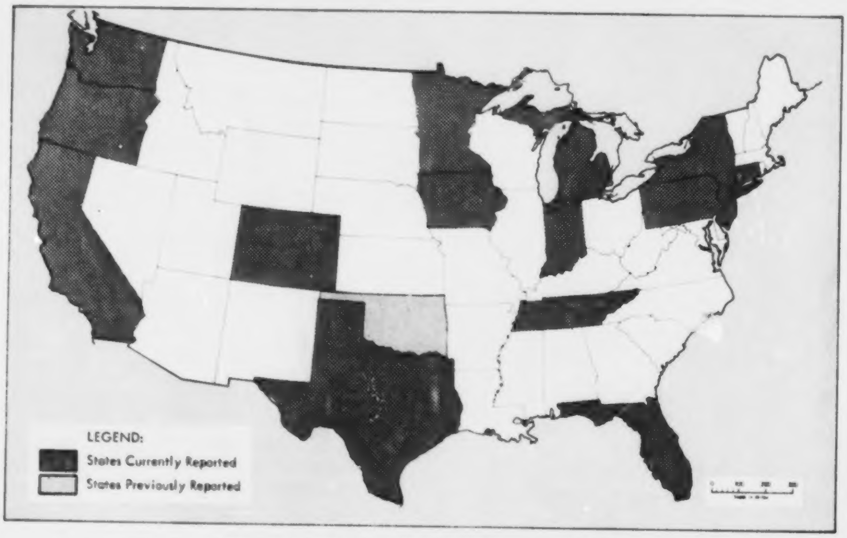

Figure 1. State milk surveillance activities

1. California Milk Network
April–July 1968

Division of Environmetal Sanitation
State of California, Department of Public Health

Surveillance of specific radionuclides in milk is one phase of the California Department of Health program on radiation control. This milk monitoring function is conducted by the Department's Bureau of Radiological Health at 10 major milksheds (figure 2).

In January 1960, the eight original sampling locations were chosen by the State Department of Agriculture so as to be representative of milk consumed by a high percentage of the State's population. The Del Norte and Mendocino milksheds were added to the program in March 1962 and since that time, weekly, biweekly or monthly sampling of pasteurized milk has been conducted in 10 milkshed areas of the State. A description of the various California milksheds was presented earlier by Heslep and Cornish (*1*).

Strontium–89 and strontium–90 concentrations are determined radiochemically. Potassium–40, iodine–131, cesium–137, and barium–140 in whole fluid milk are determined by

97

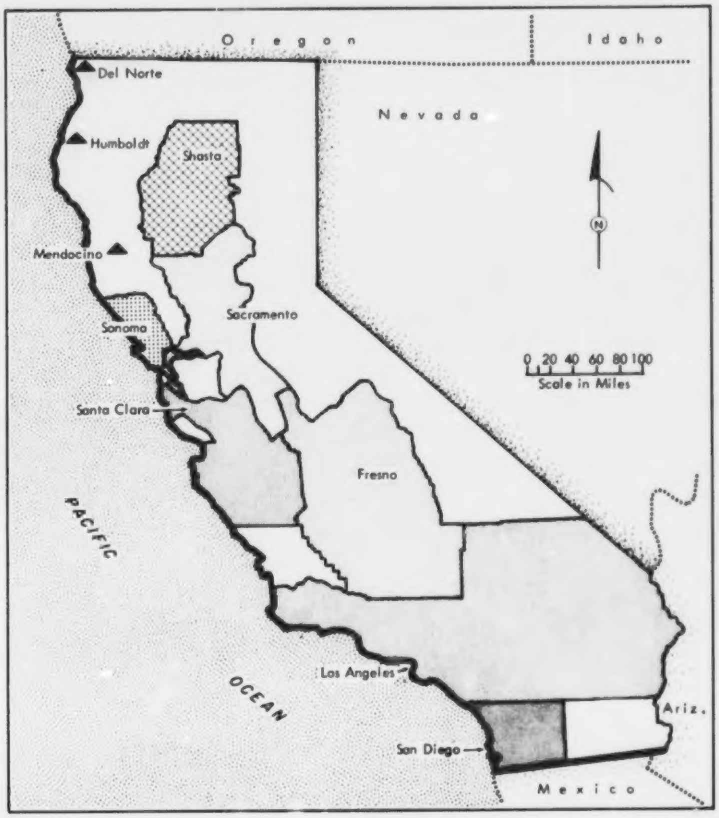
Oregon
Idaho
Nevada
Del Norte
Humboldt
Shasta
Mendocino
Sacramento
Sonoma
Santa Clara
Fresno
N
0 20 40 60 80 100
Scale in Miles
PACIFIC
OCEAN
Los Angeles
San Diego
Ariz.
Mexico

Figure 2. California milksheds

gamma-ray scintillation spectrometry. A detailed description of the analytical procedures was presented in an earlier report (*2*).

The monthly calcium, potassium and radionuclide concentrations in California pasteurized milk are given in table 1 for the period of April through July 1968. All iodine-131 concentrations remained below detectable levels of 10 pCi/liter during this period.

Network average strontium-90 and cesium-137 concentrations are presented graphically in figure 3.

Table 1. Stable elements and radionuclide concentrations in California milk, April–July 1968

Sampling location	Calcium (g/liter)				Potassium (g/liter)				Strontium-89 (pCi/liter)				Strontium-90 (pCi/liter)				Cesium-137 (pCi/liter)			
	Apr	May	June	July	Apr	May	June	July	Apr	May	June	July	Apr	May	June	July	Apr	May	June	July
Del Norte	1.36	1.32	1.34	1.25	1.5	1.5	1.6	1.6	16	6	11	4	19	20	19	15	24	19	21	15
Fresno	1.22	1.15	NA	1.08	1.6	1.5	1.5	1.5	2	ND	1	ND	1	2	1	2	ND	9	ND	ND
Humboldt	1.15	1.21	1.16	1.13	1.5	1.5	1.5	1.5	10	ND	3	ND	1	7	5	3	ND	12	13	9
Los Angeles	1.11	1.09	1.04	1.04	1.6	1.6	1.7	1.4	ND	2	1	ND	3	2	1	2	ND	ND	ND	ND
Mendocino	NA	1.29	1.06	1.08	1.5	1.5	1.6	1.5	2	3	1	ND	5	3	3	2	16	ND	ND	ND
Sacramento	1.16	1.18	1.21	1.12	NA	1.5	1.5	1.6	5	1	ND	ND	2	3	3	2	NA	10	12	11
San Diego	1.10	1.05	1.13	1.06	1.5	1.5	1.6	1.6	1	ND	ND	ND	1	1	1	1	8	ND	ND	6
Santa Clara	1.21	1.00	1.09	1.13	1.5	1.3	1.5	1.6	2	ND	ND	ND	1	2	2	1	8	19	ND	6
Shasta	1.11	1.15	1.11	1.06	1.6	1.5	1.6	1.5	ND	1	ND	ND	4	3	4	3	ND	ND	14	ND
Sonoma	1.15	1.11	1.14	1.10	1.6	1.5	1.6	1.6	5	ND	ND	ND	4	4	2	2	ND	12	10	ND

NA, no analysis.
ND, nondetectable.

98

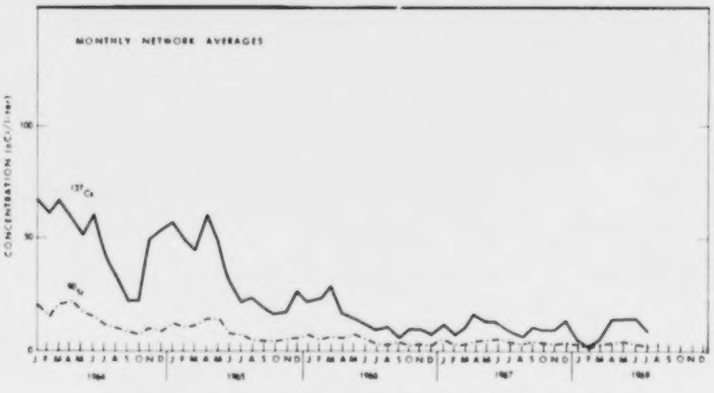

Figure 3. Radionuclide concentrations in California milk 1964–July 1968

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	June 1968
January–March 1968	September 1968

---

2. Colorado Milk Network
July 1968

Air, Occupational and Radiation Hygiene Division
Colorado State Department of Public Health

The Radiation Hygiene Section of the Colorado State Health Department initiated analysis of milk for gamma-ray emitting radionuclide in January 1962. Initially a composite milk sample from the major producers supplying the Denver area was collected by the Denver City and County Health Department for the State.

In August 1962, the State expanded this program to include the sampling of raw milk from the major milk producing areas supplying the entire State. The routine sampling rate depends on the activities of the Milk, Food and Drug Section of the State Health Department. Milkshed areas are shown in figure 4.

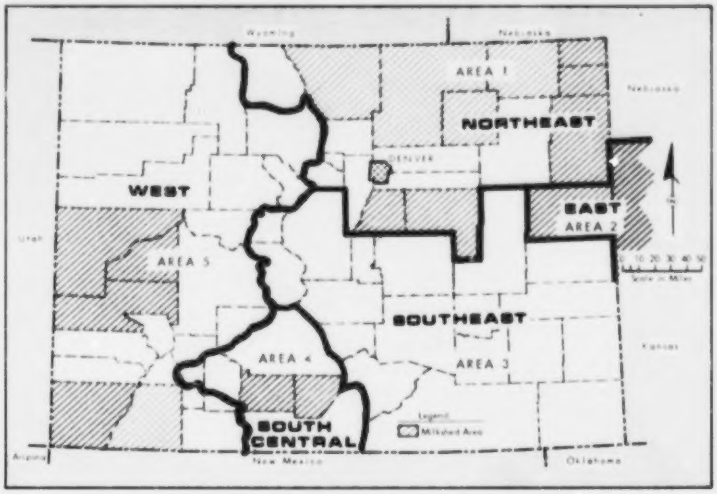
Wyoming
Nebraska
Nebraska
AREA 1
NORTHEAST
DENVER
WEST
EAST
AREA 2
Utah
AREA 5
0 10 20 30 40 50
Scale in Miles
SOUTHEAST
AREA 4
AREA 3
Kansas
Legend
Milkshed Area
SOUTH CENTRAL
Arizona
New Mexico
Oklahoma

Figure 4. Colorado milk sampling stations

Analyses are performed for iodine–131, barium-lanthanum–140, cesium–137 and potassium by gamma-ray spectrometry. Employed in this procedure is a 4- by 5-inch diameter NaI(Tl) crystal housed in a modified office safe lined with 2 inches of lead and a 512 multichannel pulse-height analyzer using a typewriter readout. Samples and backgrounds are counted for 40 minutes in a 2 quart (1,892 ml) plexiglass Marinelli beaker. Calculation is by the matrix method (*3*) and the minimum detectable concentrations are: iodine–131, 15 pCi/liter; barium-lanthanum–140, 21 pCi/liter; cesium–137, 16 pCi/liter; and potassium, 0.25 g/liter.

Four milk samples were collected and counted during July 1968. Iodine–131, barium-lanthanum–140 and cesium–137 concentrations were below their respective minimum detectable concentrations. Potassium concentrations averaged 1.5 ± 0.2 (2σ) g/liter.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–March 1968	July 1968
April–June 1968	October 1968

3. Connecticut Milk Network
April–July 1968

Connecticut State Department of Health

The Connecticut State Department of Health has been monitoring pasteurized milk for strontium–89 and strontium–90 since April 1960. In May 1962, the program was expanded to include the determination of gamma-emitting radionuclides in milk.

The sampling program is flexible in nature, providing for sampling in five areas of the State (figure 5). At the present time, weekly samples representative of milk sold in the central area of the State are collected and analyzed for strontium–89, strontium–90, and gamma-ray emitters. Concentrations of iodine–131 are determined as an indication of the presence of radioactivity of recent origin.

Table 2. Radionuclide concentrations in central Connecticut pasteurized milk, April–July 1968

Month	Radionuclide concentration (pCi/liter)			
	Strontium-89	Strontium-90	Iodine-131	Cesium-137
April	NA	7	<10	10
May	NA	8	<10	<10
June	NA	10	<10	15
July	NA	NA	<10	20

NA, no analysis.

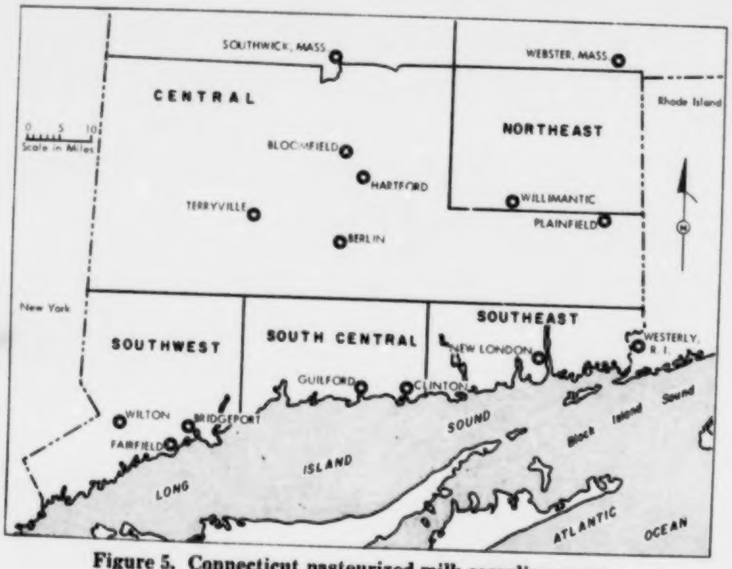
SOUTHWICK, MASS
WEBSTER, MASS
CENTRAL
Rhode Island
0 5 10
Scale in Miles
NORTHEAST
BLOOMFIELD
HARTFORD
TERRYVILLE
WILLIMANTIC
PLAINFIELD
BERLIN
N
New York
SOUTHWEST
SOUTH CENTRAL
SOUTHEAST
NEW LONDON
WESTERLY, R.I.
GUILFORD
CLINTON
WILTON
BRIDGEPORT
FAIRFIELD
SOUND
Block Island Sound
LONG
ISLAND
ATLANTIC
OCEAN

Figure 5. Connecticut pasteurized milk sampling areas

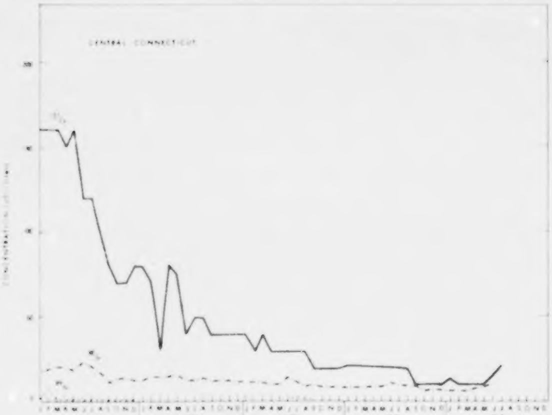

Figure 6. Radionuclides in Connecticut pasteurized milk 1964–July 1968

Strontium–89 and strontium–90 are determined by chemical separation. Iodine–131 and other gamma-ray emitters are determined by gamma-ray scintillation spectroscopy.

The monthly average concentrations of strontium–89, strontium–90, iodine–131, and cesium–137 in central Connecticut pasteurized milk are presented in table 2. These results are presented graphically in figure 6.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

---

4. Florida Milk Network
July 1968

Division of Radiological Health
Florida State Board of Health

The Florida State Board of Health began sampling raw milk for iodine–131 analysis in two major areas of the State in November 1962. The program has since been expanded to include the analysis of milk for strontium–89, strontium–90, cesium–137, barium–140 and potassium, in addition to iodine–131. Analysis for strontium–89 was made until 1965, but due to extremely low levels has been discontinued since that time. Monthly milk sample collection procedure of obtaining milk from randomly selected farms in each of the six regions of the State (figure 7), was redesigned in July 1968. Beginning in July 1968, a 1-gallon raw milk sample is collected monthly from a major processing plant in each of the regions referenced above. The milk produced in each region is generally processed and consumed in that region. The procesing plant from which the milk sample is obtained was selected on its percentage contribution to the total milk market.

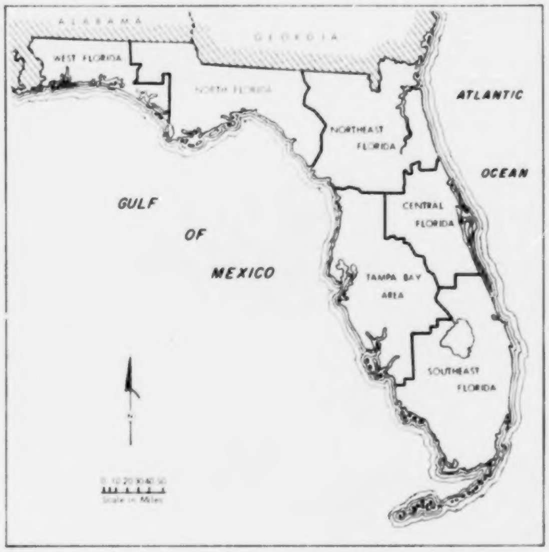

Figure 7. Florida milk sampling areas

The sample of milk is collected in each region on Monday or Tuesday following the first Sunday of each month. The maximum age of any portion of the milk making up the sample is 72 hours. The samples are sent to the State Board of Health Radiological Laboratory in Orlando for analyses. The samples are ana-

Table 3. Stable element and radionuclide concentration [a] in Florida raw milk, July 1968

Sampling location	Potassium (g/liter)	Radionuclide concentrations (pCi/liter)	
		Strontium-90	Cesium-137
	July	July	July
West	1.7	12	23
North	1.6	20	46
Northeast	1.6	17	68
Central	1.6	10	184
Tampa Bay area	1.6	7	55
Southeast	1.6	13	108

[a] Barium-140 and iodine-131 concentrations remained below 10 pCi/liter for this period.

lyzed and corrected for decay to the time and date of collection.

Strontium-90 is determined by the ion exchange method developed by Porter et al (*4*). Iodine-131, cesium-137, barium-140 and potassium are determined by gamma-ray spectrometry (*5*).

Stable element and radionuclide concentrations for July 1968 are presented in table 3.

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January-March 1968	July 1968
April-June 1968	October 1968

---

5. Indiana Milk Network
April-July 1968

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radionuclide analysis in September 1961. The State was geographically divided into five major milksheds; northeast, northwest, central, southeast, and southwest (figure 8). One large dairy within each milkshed was assumed to be representative for sampling purposes.

The milk samples are analyzed monthly for strontium-89 and strontium-90. Cesium-137, iodine-131, and barium-140 are analyzed weekly for at least two of the milksheds. When iodine-131 concentrations exceed 100 pCi/liter, the sampling frequency is increased. From August 1963 to April 1966, because of the continued low concentrations of short-lived radionuclides, the sampling frequency was once a month for the northeast, southeast, and southwest milksheds.

Strontium-89 and strontium-90 concentrations in milk samples are determined by ion exchange separation (*4, 6*) while cesium-137, iodine-131, and barium-140 are determined by gamma-ray scintillation spectrometry (*7*).

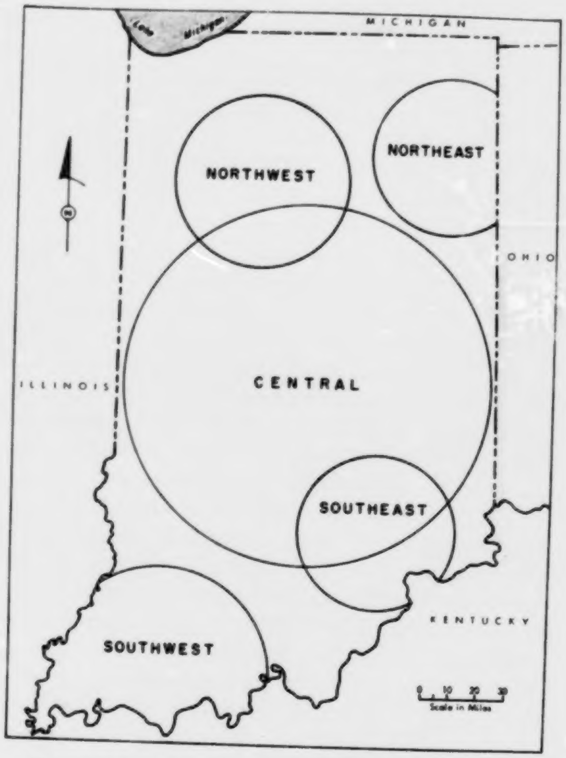

Figure 8. Indiana pasteurized milk sampling areas

The monthly stable element and radionuclide concentrations in Indiana pasteurized milk are

102

**Table 4. Stable element and radionuclide concentrations in Indiana milk [a]
April–July 1968**

Sampling location	Calcium (g/liter)				Potassium (g/liter)				Strontium-90 (pCi/liter)				Cesium-137 (pCi/liter)			
	Apr	May	June	July	Apr	May	June	July	Apr	May	June	July	Apr	May	June	July
Northeast	1.13	NA	1.29	1.16	1.5	1.6	1.5	1.6	7	7	11	10	10	10	10	10
Southeast	1.13	NA	1.28	1.13	1.7	1.6	1.4	1.7	9	11	13	11	10	20	20	5
Central	1.18	NA	1.15	1.16	1.5	1.5	1.5	1.7	7	9	9	9	5	10	10	5
Southwest	1.24	NA	1.25	1.18	1.6	1.5	1.6	1.6	7	12	13	12	10	15	15	15
Northwest	1.20	NA	1.18	1.18	1.5	1.5	1.5	1.6	8	9	11	9	10	10	15	10

[a] All strontium-89 concentrations were 0 for this period.

presented by sampling locations in table 4 for April through July 1968. Barium–140 and iodine–131 concentrations remained below detectable levels of 10 pCi/liter during this period.

The monthly network average concentrations of strontium–89, strontium–90, and cesium–137 are presented graphically in figure 9.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

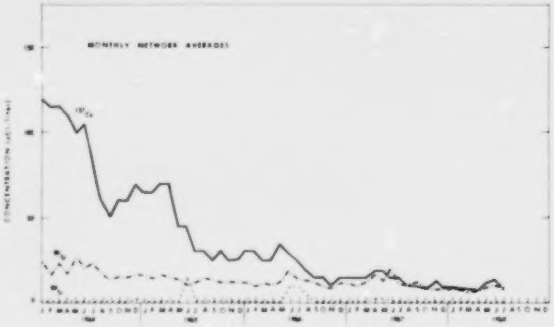

Figure 9. Radionuclide concentrations in Indiana pasteurized milk. 1964–July 1968

6. Iowa Milk Network
April–July 1968

State Hygienic Laboratory and the Iowa State Department of Health

In Iowa, radiological health activities are conducted jointly by the State Department of Health and the State Hygienic Laboratory, with the State Hygienic Laboratory performing the surveillance and analytical functions.

In August 1962 the State Hygienic Laboratory of Iowa began sampling milk for iodine–131. In May 1964 this routine surveillance was expanded to include cesium–137 and strontium–90.

One gallon samples are collected from 4 stations, selected to give a broad coverage of milk production areas in the State (figure 10). Producers furnishing milk to the Spencer bottling area are quite restricted to that northwest part of the State and the majority of milk

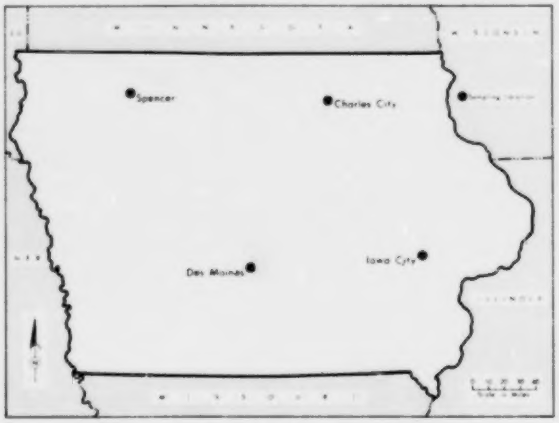

Figure 10. Iowa milk sampling locations

Table 3. Radionuclide concentrations in Iowa milk, April–July 1968

Sampling location	Concentration (pCi/liter)											
	Strontium-90				Cesium-137				Iodine-131			
	April	May	June	July	April	May	June	July	April	May	June	July
Iowa City	7	8	7	NA	<10	<10	<10	<10	<10	<10	<10	<10
Des Moines	7	7	NA	NA	<10	<10	<10	<10	<10	<10	<10	<10
Spencer	7	7	NA	NA	<10	<10	<10	<10	<10	<10	<10	<10
Charles City	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA, no analysis.

bottled in Iowa City comes from six counties in east central Iowa. The Des Moines milkshed comprises approximately 60 counties covering about two thirds of the State radiating out of Des Moines in all directions. The Charles City bottling area covers primarily north central Iowa. At present the Iowa City and Des Moines stations are sampled weekly and the Spencer and Charles City stations are sampled monthly. This sampling frequency is increased when nuclide concentrations warrant closer surveillance. The samples are forwarded to the State Hygienic Laboratory at the University of Iowa, Iowa City for analysis.

Analytical procedures

Iodine–131 and cesium–137 together with barium–lanthanum–140 and potassium–40 are determined by gamma-scintillation spectrometry using a 4- by 4-inch NAI (Tl) crystal and 512 channel pulse-height analyzer. All samples are 3.5 liters and are counted for 80 minutes in Marinelli beakers with the results being calculated using a 4 by 4 matrix. Strontium–90 is determined by an ion-exchange system described by Porter, et al (*14*). One liter of milk is passed through an ion exchange column; yttrium–90 is eluted from the resin and counted as yttrium oxalate in an automatic low background proportional counter. Minimum detectable limits are 10 pCi/liter for iodine–131 and cesium–137 and 2 pCi/liter for strontium–90.

Results

Table 4 gives the monthly averages at each of the four locations for April-July 1968 and figure 11 shows graphically the overall network average monthly results for the same period. During this period it can be seen that the concentration levels of cesium–137 and strontium–90 showed a decreasing trend. The only significant amount of iodine–131 was present during the month of June 1965.

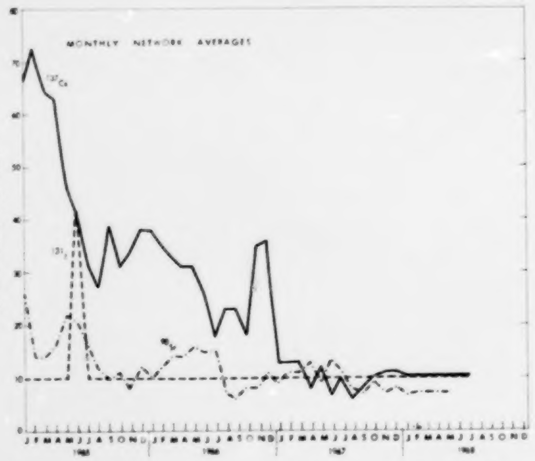

Figure 11. Radionuclide concentrations in Iowa milk, 1965–July 1968

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

7. Michigan Milk Network
April–July 1968

Division of Occupational Health
Michigan Department of Health

The Michigan Department of Health began sampling pasteurized milk for radionuclide analyses in November 1962. Under this program, weekly pasteurized milk samples are collected in the seven major milk producing areas in the State: Charlevoix, Detroit, Grand Rapids, Lansing, Marquette, Monroe, and Saginaw (figure 12). Milkshed samples are composites of dairies in proportion of sales volumes.

Strontium-90 concentrations are determined by an ion exchange method (*8*). Potassium-40, iodine-131, cesium-137, and barium-lanthanum-140 concentrations are determined by gamma-ray scintillation spectrometry (*8*).

Table 6 presents the monthly average radionuclide concentrations in Michigan pasteurized

Table 6. Radionuclide concentrations in Michigan pasteurized milk, April–July 1968

Sampling location	Month	Potassium (g/liter)	Strontium-90 (pCi/liter)	Iodine-131 (pCi/liter)	Cesium-137 (pCi/liter)
Charlevoix	April	1.6	4	<14	10
	May	NA	NA	NA	NA
	June	NA	NA	NA	NA
	July	NA	NA	NA	NA
Detroit	April	1.6	4	<14	10
	May	1.6	4	<14	11
	June	1.5	NA	<14	14
	July	1.6	7	<14	11
Grand Rapids	April	1.6	5	<14	12
	May	1.6	5	<14	10
	June	1.6	NA	<14	13
	July	1.6	5	<14	15
Lansing	April	1.6	2	<14	7
	May	1.6	4	<14	10
	June	1.6	NA	<14	9
	July	1.6	5	<14	11
Marquette	April	1.6	7	<14	19
	May	1.6	8	<14	19
	June	1.5	6	<14	27
	July	1.6	1	<14	40
Monroe	April	1.6	3	<14	6
	May	1.6	3	<14	5
	June	1.6	3	<14	5
	July	1.6	7	<14	8
Bay City	April	1.6	4	<14	10
	May	NA	NA	NA	NA
	June	1.6	NA	<14	13
	July	1.6	5	<14	15

NA, no analysis.

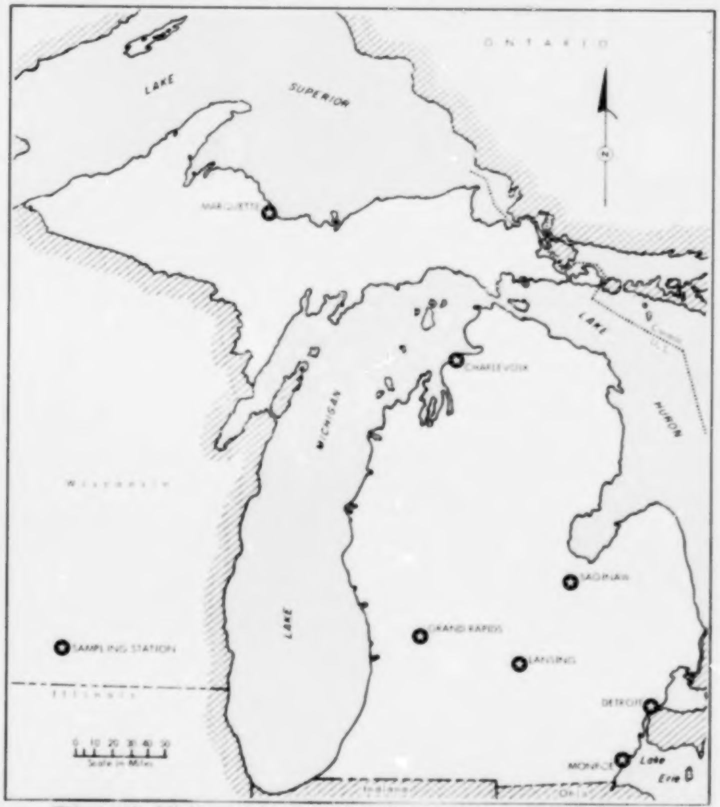
ONTARIO
LAKE
SUPERIOR
N
MARQUETTE
LAKE
CHARLEVOIX
MICHIGAN
HURON
WISCONSIN
SAGINAW
LAKE
GRAND RAPIDS
SAMPLING STATION
LANSING
ILLINOIS
DETROIT
0 10 20 30 40 50
Scale in Miles
MONROE
Lake
Erie
Indiana
Ohio

Figure 12. Michigan pasteurized milk network sampling locations

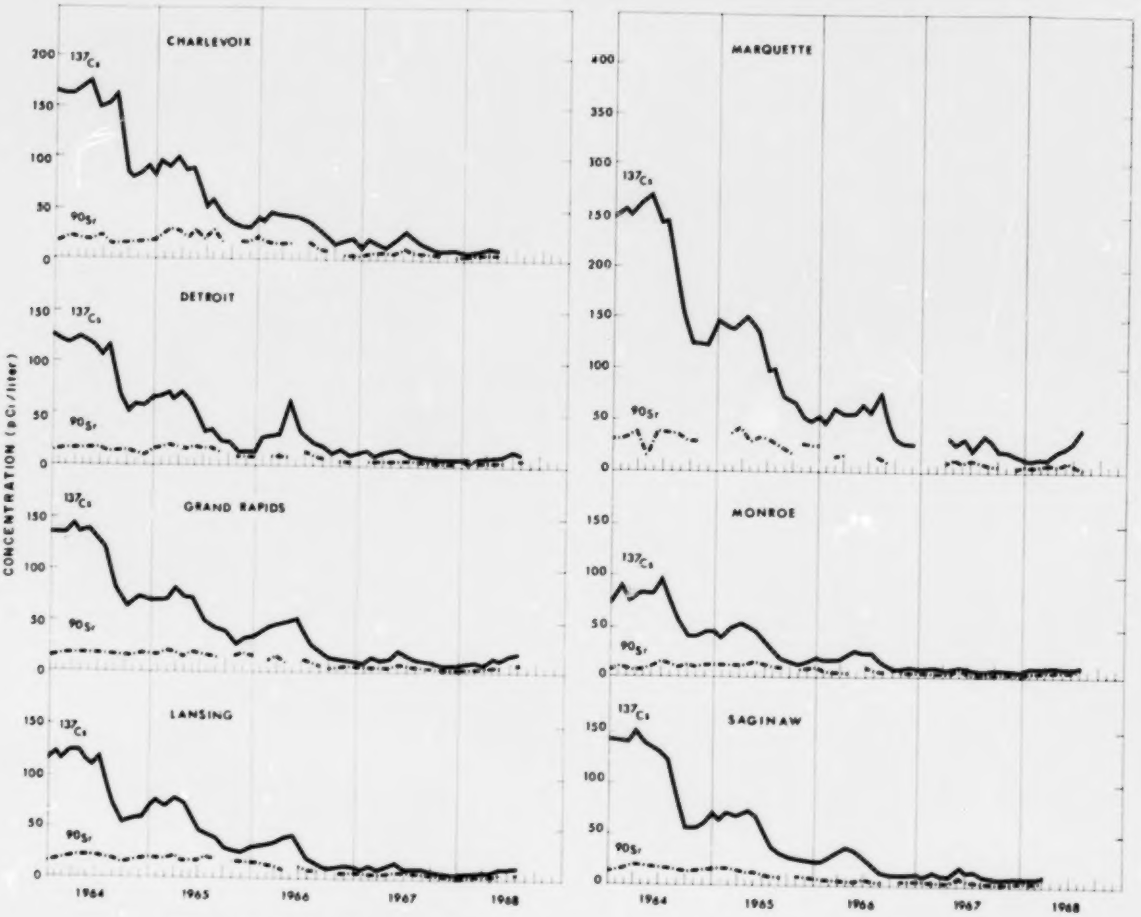

Figure 13. Radionuclide concentrations in Michigan pasteurized milk, 1964–July 1968

milk. Iodine–131 levels were less than the minimum detectable radioactivity (14 pCi/liter) for the period at all stations. Strontium-90 and cesium-137 concentrations are presented graphically in figure 13 to show general trends.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

8. Minnesota Milk Network April–July 1968

Division of Environmental Health
Minnesota Department of Health

In September 1958, the Minnesota Department of Health initiated a pasteurized milk network to monitor strontium-90 concentrations. Monitoring of iodine-131 concentrations commenced in October 1961 and of cesium-137 concentrations in July 1963. Until recently, one-liter samples were collected from eight sampling locations in milksheds geographically the same as the Minnesota health districts (figure 14) and analyzed for strontium-90, iodine-131, and cesium-137. The size of the sample has been increased to 2 quarts for more accurate determinations. The 2-quart samples of processed Grade A fluid milk are collected in the cities where the Minnesota Health Department district offices are located.

Strontium-90 concentrations are determined radiochemically, while iodine-131 and cesium-137 concentrations are determined by gamma ray scintillation spectrometry. The analytical procedures are presented in the semiannual report of the Minnesota Department of Health and the Rural Cooperative Power Association (*9*).

Strontium-90, and cesium-137 concentrations in milk are given for April through July 1968 in table 7, and are presented graphically by milkshed in figure 15 for the period, 1964 through July 1968. Iodine-131 concentrations were less than 10 pCi/liter in all 24 samples.

Table 7. Radionuclide concentrations in Minnesota pasteurized milk, April–July 1968

Station	Radionuclide concentrations (pCi/liter)							
	Strontium-90				Cesium-137			
	Apr	May	June	July	Apr	May	June	July
Bemidji	15	16	16	19	28	30	30	21
Mankato	6	5	5	3	15	11	7	<4
Rochester	7	10	11	11	10	7	10	22
Duluth	19	18	24	26	40	26	38	44
Worthington	6	5	6	8	12	5	8	15
Minneapolis	10	13	15	18	15	14	13	26
Fergus Falls	8	18	8	12	13	13	15	15
Little Falls	8	9	12	10	15	15	11	21

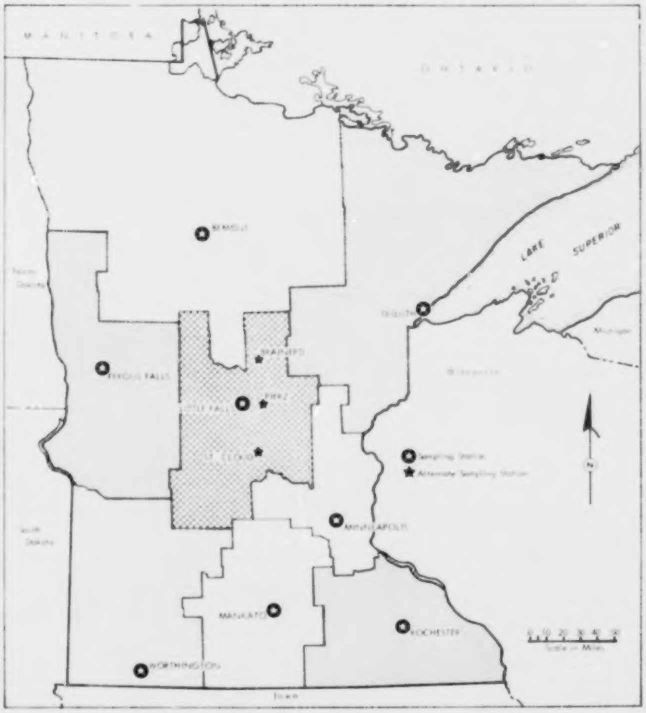
MANITOBA
ONTARIO
BEMIDJI
North Dakota
LAKE SUPERIOR
DULUTH
Michigan
Wisconsin
BRAINERD
FERGUS FALLS
PIERZ
LITTLE FALLS
ST. CLOUD
Sampling Station
Alternate Sampling Station
N
South Dakota
MINNEAPOLIS
MANKATO
ROCHESTER
0 10 20 30 40 50
Scale in Miles
WORTHINGTON
Iowa

Figure 14. Minnesota milk sampling locations

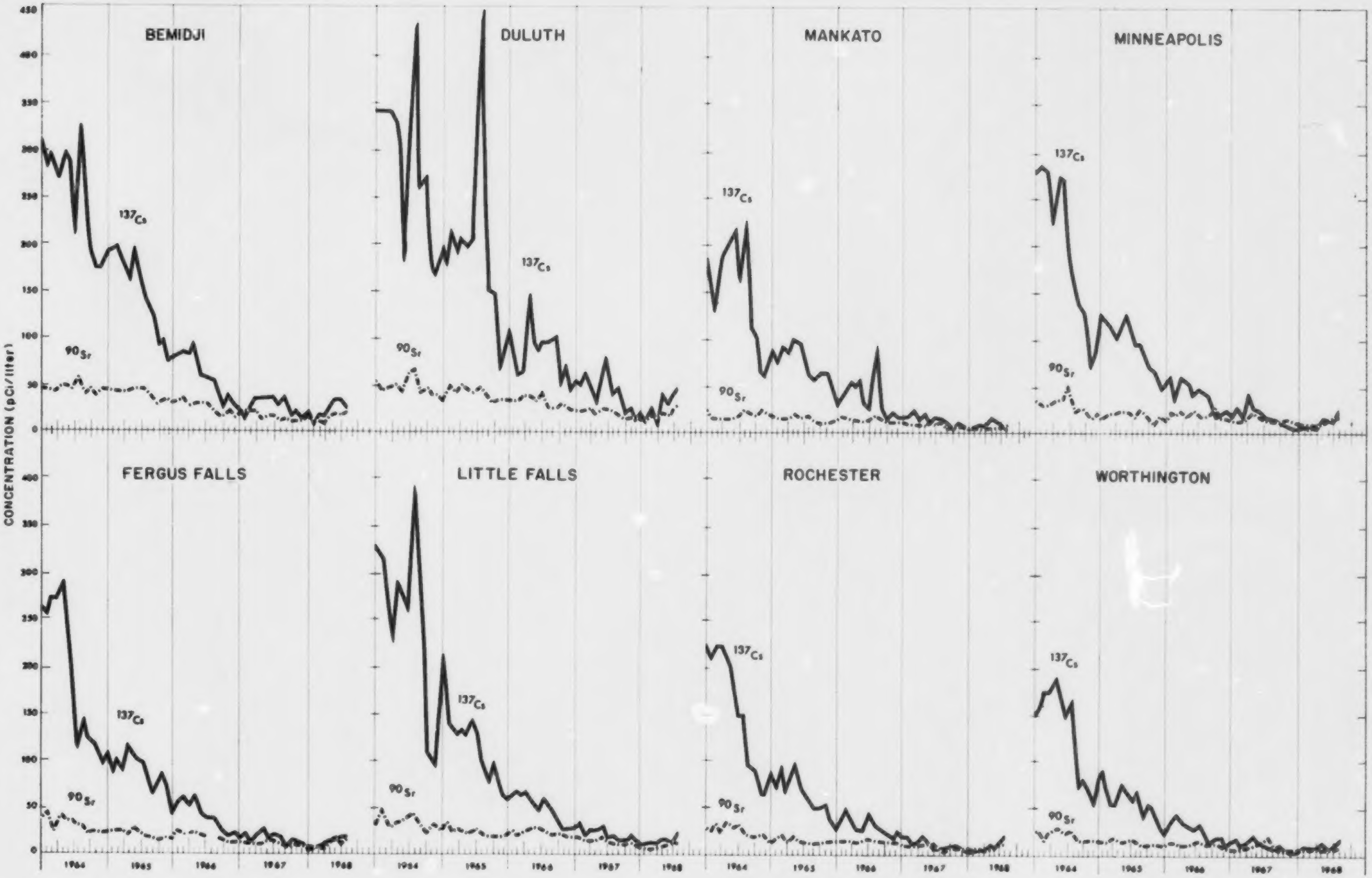

Figure 15. Radionuclide concentrations in Minnesota milk, 1964–July 1968

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

9. New York Milk Network
April–July 1968

Division of General Engineering and
Radiological Health
Department of Health, State of New York

Pasteurized milk samples collected routinely from six cities (figure 16 are analyzed for strontium–89, strontium–90, iodine–131, cesium–137 and barium-lanthanum–140 by the from six cities (figure 16) are analyzed for New York State Department of Health. At Buffalo and Newburgh, milk samples are collected daily from processing plants and composited weekly for radiochemical analyses. At Messena, and Syracuse daily samples are composited over a 2-week period and then analyzed. In New York City, a milk sample representing the total milk supply for 1 day is analyzed weekly. The Albany sample, taken at a marketing point, is analyzed daily for iodine–131 and other gamma-ray emitting radionuclides before being composited into a weekly sample. In the event that any sample contains iodine–131 concentrations exceeding 100 pCi/liter, increased surveillance is undertaken.

Gamma-ray emitting radionuclides in milk are determined by scintillation spectrometry. Radioiodine is selectively removed in an anion exchange resin and the resin is analyzed for iodine–131 (*11, 13*). The resin effluent is analyzed and the resulting spectral data is resolved by the application of a matrix method of analysis (*12*).

The analytical procedure for determining strontium–89 and strontium–90 concentrations employs an ion-exchange system similar to that developed by Porter, et al (*6*).

The radionuclide concentration of strontium–90 and cesium–137 are shown in table 8 for

Table 8. Radionuclide concentrations in New York pasteurized milk, April–July 1968

Sampling location	Date	Radionuclide concentrations (pCi/liter)	
		Strontium-90	Cesium-137
Albany	April	7	ND
	May	10	ND
	June	7	ND
	July	9	21
Buffalo	April	7	ND
	May	5	ND
	June	8	ND
	July	4	ND
Massena	April	8	25
	May	10	25
	June	10	33
	July	18	31
Newburgh	April	7	ND
	May	12	ND
	June	NS	NS
	July	12	ND
New York City	April	9	22
	May	11	23
	June	14	26
	July	12	24
Syracuse	April	7	ND
	May	8	ND
	June	NS	NS
	July	NA	ND

ND, nondetectable.
NS, no sample.
NA, no analysis.

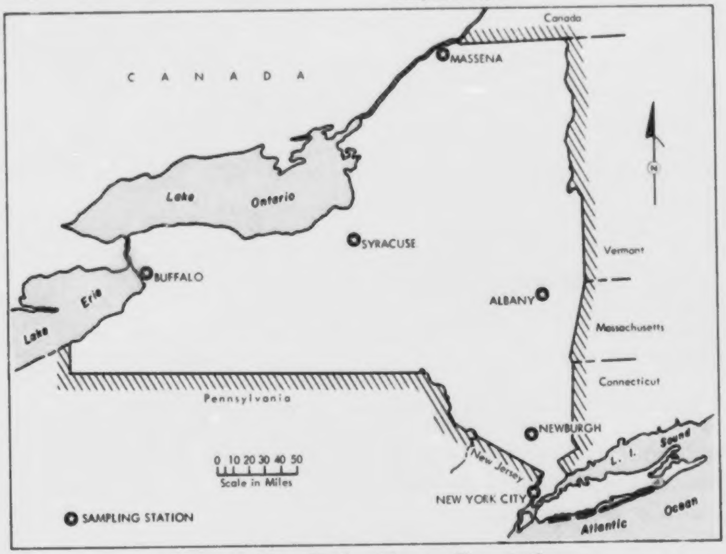

Figure 16. New York milk sampling stations

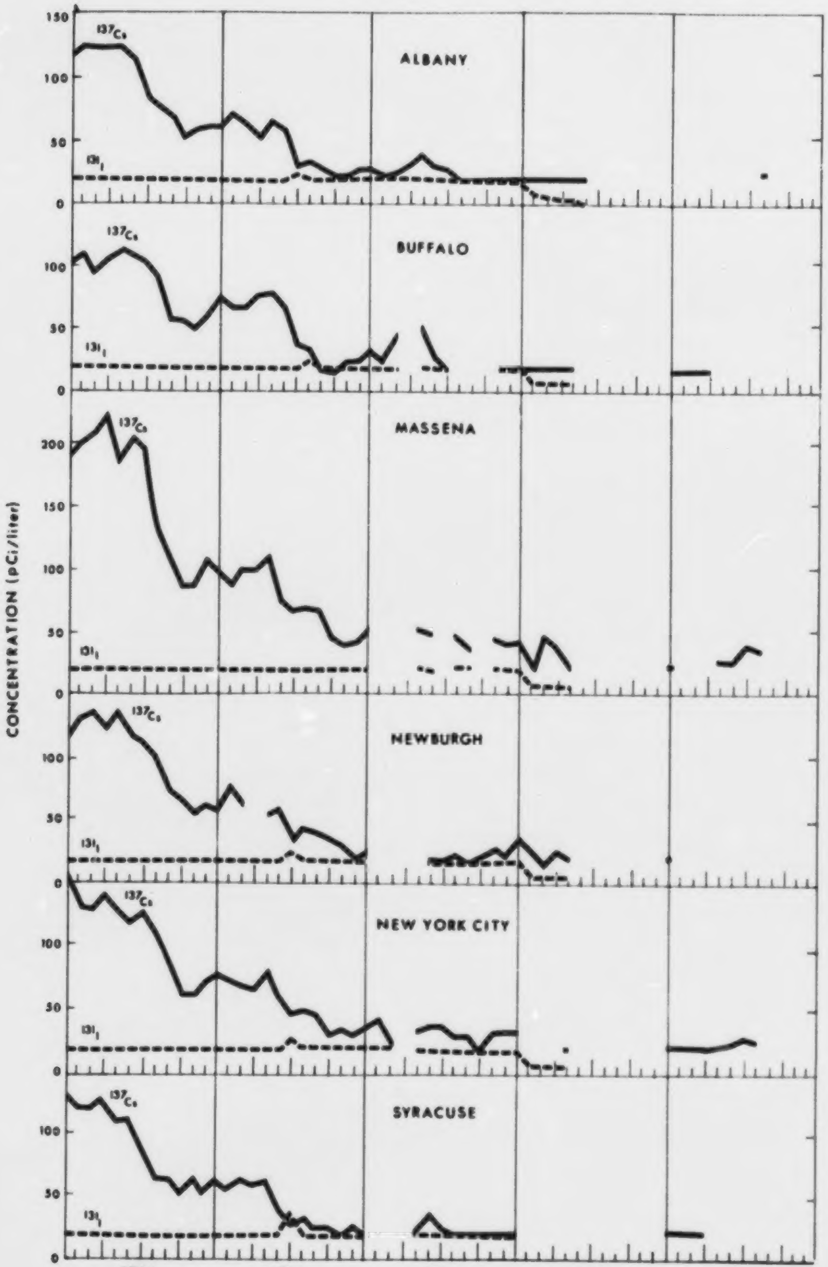

Figure 17. Radionuclide concentrations in New York milk, 1964–July 1968

April through July 1968. Cesium–137 and iodine–131 concentrations since January 1964 are presented graphically in figure 17.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

10. Oregon Milk Network
April–July 1968

Division of Sanitation and Engineering
Oregon State Board of Health

The Oregon State Board of Health has monitored radionuclide concentrations in milk since March 1962. As part of this program routine milk samples are collected at seven major production areas (figure 18), which supply 90 percent of the milk distributed in Oregon. Currently, pasteurized milk samples are collected monthly by the Oregon Department of Agriculture, except in the Portland area where weekly samples are collected by the city of Portland. The milk sampling frequency is accelerated to a weekly basis in areas where iodine–131 concentrations exceed 100 pCi/liter, or when cesium–137 concentrations exceed 500 pCi/liter. Strontium–90 analyses are performed on a bimonthly basis, but may be done monthly when significant increases are observed.

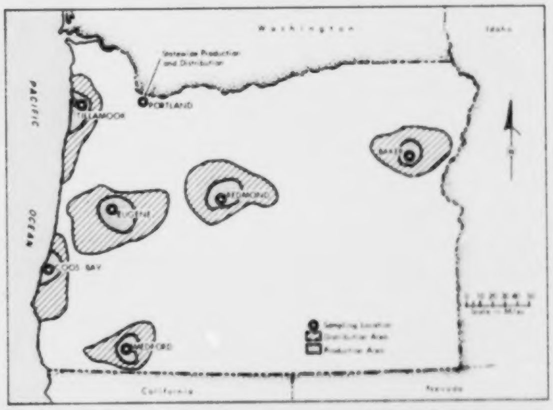

Figure 18. Oregon milk production and distribution areas

Strontium–90 concentrations are determined using a trichloracetic acid analytical procedure (*15*). Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma-ray scintillation spectrometry (*16*).

Table 9. Radionuclide concentrations in Oregon pasteurized milk, April–July 1968

Location	Sampling frequency [a]	Strontium-90 (pCi/liter)				Cesium-137 (pCi/liter)			
		Apr	May	June	July	Apr	May	June	July
Baker	M	NA	NA	NA	3	<15	<15	<15	<15
Coos Bay	M	NA	20	NA	16	<15	16	26	15
Eugene	M	NA	4	NA	4	21	<15	15	15
Medford	M	NA	4	NA	2	<15	<15	17	<15
Portland composite	W	NA	NA	NA	8	17	23	18	20
Portland local	W	NA	NA	NA	7	17	28	21	18
Redmond	M	NA	NA	NA	4	<15	17	<15	<15
Tillamook	M	NA	NA	NA	NA	18	56	42	20

[a] M, sampled monthly.
W, sampled weekly.
NA, no analysis.

Table 9 gives the strontium–90 and cesium–137 concentrations in pasteurized milk from April through July 1968. These data are presented graphically in figure 19. Iodine–131 and barium–140 concentrations remained below minimum detectable levels of 15 pCi/liter for all samples which were collected in April through July 1968.

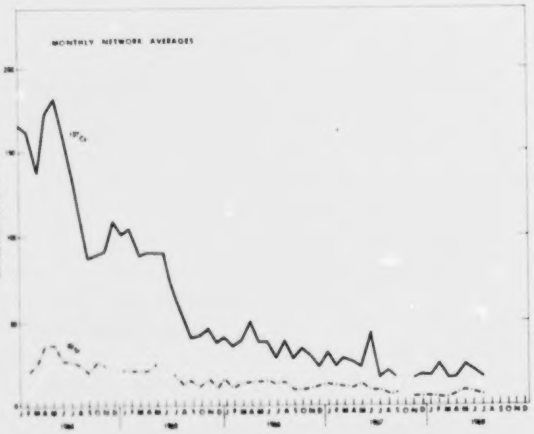

Figure 19. Radionuclide concentrations in Oregon milk network, 1964–July 1968

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	June 1968
January–March 1968	September 1968

11. Pennsylvania Milk Network
April–July 1968

Bureau of Environmental Health
Pennsylvania Department of Health

Samples of pasteurized milk are routinely collected from four major milk consumption areas throughout Pennsylvania (figure 20).

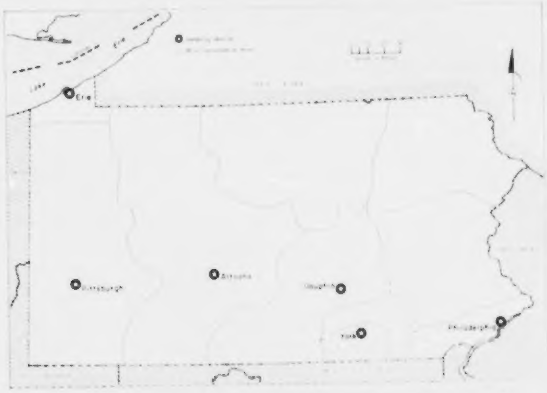

Figure 20. Pennsylvania pasteurized milk network sampling stations

Samples are collected weekly in Pittsburgh, while biweekly composite samples are now collected from the other three stations. At each sampling location, sub-samples are collected from the major dairies supplying the area and are composited in proportion to the amount of milk processed by each dairy. This composite is then sent to the Radiation Laboratory of the Division of Occupational Health in Harrisburg where the samples are analyzed for iodine–131, potassium–40, and cesium–137 and then composited for a monthly analysis of strontium–90. Stronium–90 analyses have been carried out since April 1963.

The monthly average potassium–40, strontium–90, iodine–131, and cesium–137 concentrations in pasteurized milk are given in table 10. For comparative purposes, strontium–90, iodine–131, and cesium–137 concentrations are presented graphically in figure 21.

The chemical separation technique for strontium–90 is essentially an ion-exchange method described by Porter, et al (*17*).

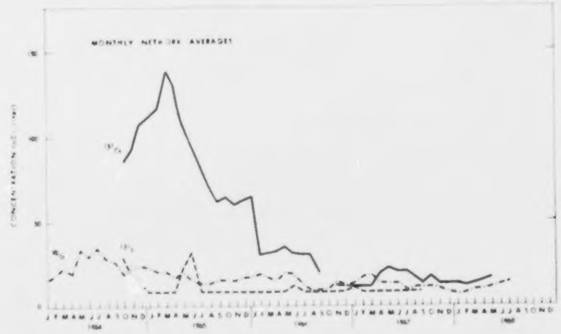

Figure 21. Radionuclide concentrations in Pennsylvania milk, 1964–July 1968

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

Table 10. Radionuclide concentrations in Pennsylvania pasteurized milk
April–July 1968

Sampling location	Potassium (g/liter)				Strontium-90 (pCi/liter)				Cesium-137 (pCi/liter)			
	April	May	June [b]	July [c]	April	May	June	July	April	May	June [b]	July [c]
Altoona [a]	1.6	NS	NS	NS	9	NS	NS	NS	9	NS	NS	NS
Dauphin	1.4	1.6	NA	1.6	5	10	10	4	21	12	NA	23
Erie	1.7	1.7	NA	1.5	14	12	16	16	22	18	NA	49
Philadelphia	1.5	1.5	NA	1.6	10	11	11	15	13	17	NA	28
Pittsburgh	1.6	1.5	NA	1.7	14	11	12	16	13	17	NA	26
York [a]	1.6	NS	NS	NS	10	NS	NS	NS	8	NS	NS	NS

[a] Sampling discontinued after April.
[b] Gamma analysis for June is missing due to analyzer malfunction.
[c] Gamma results for July are in doubt due to need for recalibration following June breakdown.
NS, no smple.
NA, nao analysis.

12. Tennessee Milk Network
July 1968

Division of Preventable Diseases
Department of Public Health
State of Tennessee

The Tennessee Department of Public Health began sampling pasteurized milk for radionuclide analysis in July of 1965. Currently the Department is collecting semimonthly milk samples from four cities (figure 22). In order to obtain a representative sample of the milk consumed in the areas monitored, a sample of milk is collected from each milk distributor supplying the city. The samples from the individual distributors are then composited in proportion to the contribution each makes to the total city milk supply.

Analytical procedures

The semimonthly milk samples from each city sampled are analyzed by gamma-ray scintillation spectrometry for potassium-40, iodine-131, cesium-137, and barium-140, using a 3½-liter sample (*14*). After gamma-ray analysis, strontium-89, strontium-90, and barium-140 concentrations are determined radiochemically using ion-exchange procedures (*15*). Chemical analyses are also made for stable calcium and potassium.

The Chattanooga milk sample is monitored by both the State and the Public Health Service's Southeastern Radiological Health Laboratory. This dual examination of aliquot samples provides a crosscheck between the two laboratories.

Results

The monthly average stable element and radionuclide concentrations in Tennessee pasteurized milk are presented in table 11 for July 1968.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–March 1968	July 1968
April–June 1968	October 1968

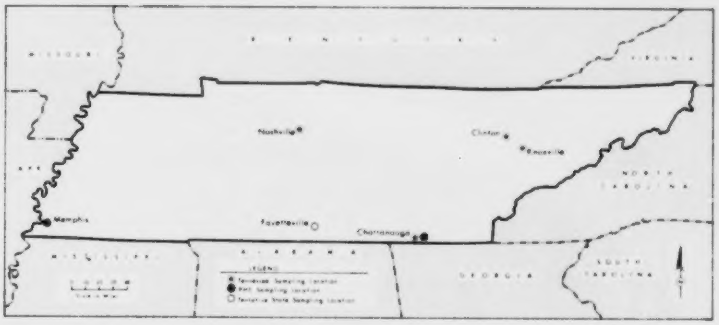

Figure 22. Tennessee pasteurized milk sampling areas

Table 11. Radionuclides in Tennessee pasteurized milk July 1968

Location	Concentration (g/liter)	Radionuclide concentration (pCi/liter)				
	Potassium	Strontium-89	Strontium-90	Iodine-131	Cesium-137	Barium-140
Chattanooga	1.5	32	5	<9	24	<8
Clinton	1.6	13	13	<9	19	<8
Knoxville	1.6	10	7	<9	20	<8
Nashville	1.6	8	6	<9	25	<8

13. Texas Milk Network
July 1968

Texas State Department of Health[1]

The Texas State Department of Health initiated a statewide milk sampling network for radionuclide content in April 1964. At present, samples of raw milk are collected from each of twelve sampling points once each calendar quarter. The station locations shown in figure 23 were chosen to give maximum geographical and population coverage.

Samples are routinely analyzed for strontium-90 by a chemical separation technique employing ion exchange columns (*17*). Prepared samples are counted for 100 minutes in a low-background beta-particle counter.

Potassium-40, iodine-131, barium-140 and cesium-137 concentrations are determined by gamma-ray spectrometry. The procedure employs a 4- by 4-inch sodium iodide crystal and a 400-channel analyzer. Samples are counted for 100 minutes in a 3.5 liter Marinelli beaker. The matrix method of calculation is used and detection limits at the 95-percent confidence level are 10 pCi/liter.

Table 12. Stable element and radionuclide concentrations in Texas raw milk network, July 1968 [a]

Sampling location	Potassium (g/liter)	Radionuclide concentrations (pCi/liter)	
		Strontium-90	Cesium-137
	July	July	July
Amarillo	NA	NA	NA
Corpus Christi	NA	NA	NA
El Paso	NA	NA	NA
Fort Worth	1.4	8	10
Harlingen	NA	NA	NA
Houston	1.5	14	15
Lubbock	NA	NA	NA
Midland	1.5	5	([b])
San Antonio	NA	NA	NA
Texarkana	NA	NA	NA
Uvalde	1.2	NA	([b])
Wichita Falls	NA	NA	NA

[a] Samples collected on a quarterly frequency at each sampling location.
[b] Below detectable limits.
NA, no analysis.

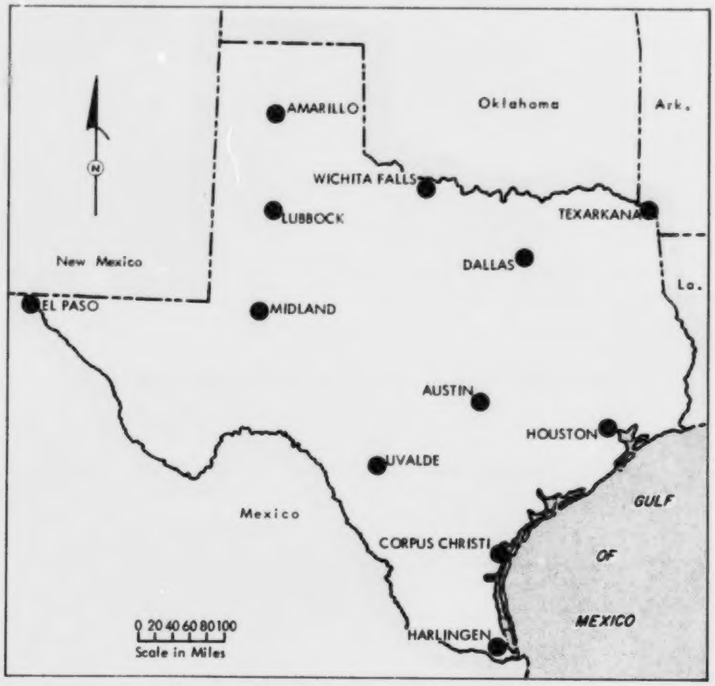

Figure 23. Texas milk sampling stations

---

[1] Acknowledgement is accorded to the staff of the Radiation Control Program, Division of Occupational Health and Radiation Control, under the direction of Mr. Martin C. Wukasch, chief engineer.

Results

Potassium–40, strontium–90 and cesium–137 results by station and month for July 1968 are presented in table 12. During this time, iodine–131 and barium–140 concentrations were below their limits of detectability (10 pCi/liter).

Comparison of the observed radionuclide concentrations with the Federal Radiation Council guides for peacetime operation indicates that at no time during the period of surveillance did the radionuclide concentrations in Texas milk approach levels suggesting any remedial action (*10*).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–March 1968	July 1968
April–June 1968	October 1968

14. Washington Milk Network
April–July 1968

Office of Air Quality Control
State of Washington Department of Health

The Washington State Department of Health initiated a surveillance program for radioactivity in raw milk in December 1962. The collection points shown in figure 24 were selected to provide samples representative of varying climatological conditions within the State's two major milksheds. In addition to the eight milk sampling locations in Washington, milk is sampled from Northwest Idaho (Sandpoint), as this area forms a part of the Spokane milkshed. Details of the sampling procedures were presented in an earlier report (*18*).

Selected samples are radiochemically analyzed for strontium–90. Potassium–40, iodine–131, cesium–137, and barium–140 concentrations are determined by gamma-ray scintillation spectrometry. Details of the analytical procedures were presented earlier (*17*).

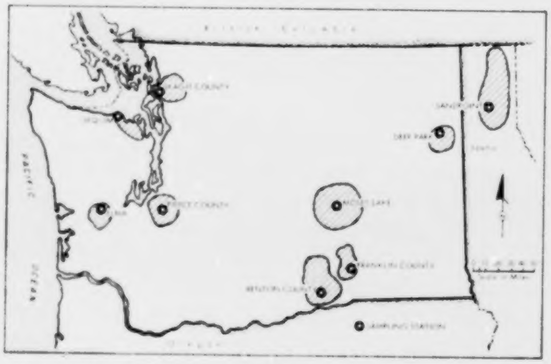

Figure 24. Washington milksheds and sampling locations

Table 13 presents monthly radionuclide concentrations in Washington raw milk for April through July 1968. Samples collected during April through July 1968 contained less than 10 pCi/liter of iodine–131. Barium–140 results remained below 15 pCi/liter for all samples collected during this period. Monthly average strontium–90 and cesium–137 concentrations are presented graphically in figure 25 to display general trends.

Table 13. Stable element and radionuclide concentrations in Washington raw milk, April–July 1968

Sampling location	Potassium (g/liter)				Radionuclide concentrations (pCi/liter)							
					Strontium-90				Cesium-137			
	April	May	June	July	April	May	June	July	April	May	June	July
Benton County	NS	1.7	NS	1.5	NS	<1	NS	1	NS	<15	NS	<15
Deer Park	1.6	1.6	1.6	1.4	5	3	5	2	<15	<15	<15	21
Elma	1.7	1.6	1.5	1.5	2	8	10	4	<15	47	35	16
Franklin County	1.6	NS	1.5	NS	1	NS	1	NS	<15	NS	<15	NS
Moses Lake	1.7	1.6	1.5	1.5	2	1	2	<1	<15	<15	<15	<15
Pierce County	1.6	1.7	1.5	1.6	1	5	6	6	<15	19	<15	24
Sandpoint, Idaho	1.5	1.6	1.6	1.4	7	—	10	8	22	18	30	30
Skagit County	1.4	1.5	1.6	1.5	8	2	5	2	26	30	24	18

NS, no sample.

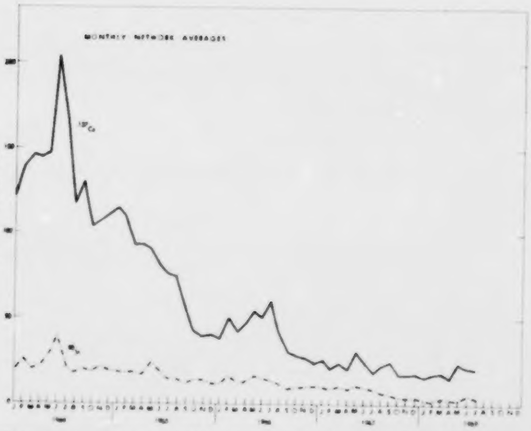

Figure 25. Radionuclide concentrations in Washington milk, 1963–July 1968

During this reporting period, four samples (two from Benton County and two from Franklin County) were analyzed for zinc-65. Results ranged from <20 pCi/liter to 47 pCi/liter of zinc-65. Milk samples produced in areas using Columbia River water for irrigation have periodically been found to contain this radionuclide.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	June 1968
January–March 1968	September 1968

REFERENCES

(*1*) HESLEP, J. M. and A. C. CORNISH. California milk network and milkshed comparisons, April–June 1963. Radiol Health Data 4:596–599 (December 1963).

(*2*) STATE OF CALIFORNIA DEPARTMENT OF PUBLIC HEALTH. California milk network, 1960–June 1962. Radiol Health Data 4:90–92 (February 1963).

(*3*) COLORADO STATE DEPARTMENT OF PUBLIC HEALTH, OCCUPATIONAL AND RADIOLOGICAL HEALTH DIVISION. Colorado milk network, October–December 1964 and summary 1962–1964. Radiol Health Data 6:202–204 (April 1965); January 1965–June 1966. Radiol Health Data Rep 7:573–575 (October 1966).

(*4*) PORTER, C., D. CAHILL, R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Improved determination of strontium-90 in milk by ion-exchange method. Anal Chem 33:1306–1309 (September 1961).

(*5*) FLORIDA STATE BOARD OF HEALTH, DIVISION OF RADIOLOGICAL HEALTH. Florida milk network, July–December 1964. Radiol Health Data 6:611–612 (November 1965).

(*6*) PORTER, C. and B. KAHN. Improved determinations of strontium-90 in milk by an ion exchange method. Anal Chem 36:676–678 (March 1964).

(*7*) INDIANA STATE BOARD OF HEALTH, BUREA OF ENVIRONMENTAL SANITATION. Indiana milk network, April–June 1965. Radiol Health Data 6:612–614 (November 1965).

(*8*) MICHIGAN DEPARTMENT OF HEALTH. Michigan milk network, November 1963–December 1964. Radiol Health Data 6:487–492 (September 1965).

(*9*) MINNESOTA DEPARTMENT OF HEALTH AND RURAL COOPERATIVE POWER ASSOCIATION. Survey of environmental radioactivity, January–June 1965, COO-615-17. Minnesota Department of Health and Rural Cooperative Power Association (August 1965).

(*10*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

(*11*) JOHNSON, R. H. and T. C. REAVEY. Evaluation of ion exchange cartridges for field sampling of iodine-131 in milk. Nature 208:750–752 (November 1965).

(*12*) KAHN B., G. K. MURTHY, C. PORTER, G. R. HAGEE, G. J. KARCHES, and A. S. GOLDIN. Rapid methods for estimating fission product concentrations in milk. PHS Publication No. 999-R-2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*13*) PORTER, C. R. and M. W. CARTER. Field method for rapid collection of iodine-131 from milk. Public Health Rep 80:453–456 (May 1965).

(*14*) PORTER, C. R., R. AUGUSTINE, J. MATUSEK, JR., and M. CARTER. Procedures for determining stable nuclides in environmental samples. PHS Publication 999-RH-10. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (January 1965).

(*15*) PORTER, C. R., M. W. CARTER, B. KAHN, and E. W. PEPPER. Rapid field method for the collection of radionuclides from milk. Proceedings of the First International Congress of the International Radiation Protection Association held in Rome, Italy, September 5–10, 1966 (in press).

(*16*) OREGON STATE BOARD OF HEALTH, DIVISION OF SANTITATION AND ENGINEERING. Oregon milk network, April–June 1965. Radiol Health Data 6:683–684 (December 1965).

(*17*) PORTER, C. D., R. SCHNEIDER, P. ROBBINS, W. PERRY, and B. KAHN. Improved determinations of strontium-90 in milk by an ion exchange method. Anal Chem 36:676–678 (March 1964).

(*18*) STATE OF WASHINGTON DEPARTMENT OF HEALTH, AIR AND RADIATION CONTROL SECTION. Washington milk network, January–June 1965. Radiol Health Data 6:619–621 (November 1965).

116

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows:

Programs	Period reported	Last presented
California Diet Study	July-October 1967	May 1968
Institutional Diet, PHS	January-March 1968	October 1968
Tri-City Diet, HASL	April-December 1967	June 1968

---

1. Estimated Daily Intake of Radionuclides in Connecticut Standard Diet, January–June 1968

Connecticut State Department of Health

The Connecticut State Department of Health has been analyzing a standard diet on a monthly basis since March 1963. Analyses are made for strontium–89, strontium–90, and gamma-ray emitters.

The standard diet was selected to represent the food intake of an 18-year-old boy for 1 day (table 1). The total weight of the complete blended diet, averaging 3 kilograms, included milk and dairy products. When raw fruit or vegetables were sampled, they were washed before blending.

Cesium–137 concentrations were determined by gamma-ray spectrometry (*1*). Strontium–89 and strontium–90 concentrations were determined by chemical separation techniques (*1*).

Table 1. Foods included in standard diet

Bread, white—8 slices
Butter, ½ stick
Carrots, scraped—½ cup
Celery, washed and trimmed—3 stalks
Cookies—4
Cottage cheese—⅔ cup
Cupcakes—2
Egg—1
Green beans, washed—½ cup
Ham—85 grams
Hamburger—227 grams
Ice cream—⅓ pint
Lettuce, washed—4-5 leaves
Milk—3 cups
Oatmeal—uncooked—43 grams
Orange—1
Peanut butter—2½ tablespoons
Pears, canned—2 halves with juice
Potatoes, washed, not peeled—2
Sugar—5 tablespoons
Tomato juice—113 grams
Tuna fish, drained—43 grams

Table 2 presents the analytical results for the Connecticut standard diet from January through June 1968. Results representative of the total daily intake for the radionuclides observed are presented in table 3.

In order to evaluate general trends, the strontium–90 and cesium–137 daily intakes are plotted as a function of time in figures 1 and 2.

Table 2. Radionuclide concentrations in Connecticut standard diet,[a] January–June 1968

Month (1968)	Potassium (g/kg)	Strontium-90 (pCi/kg)	Cesium-137 (pCi/kg)
January	2.3	7	10
February	2.1	7	10
March	2.0	8	<10
April	2.0	8	20
May	NA	NA	NA
June	2.4	10	20

[a] All strontium-89 values were <3 for this period.

Table 3. Daily radionuclide intakes in Connecticut standard diet,[a] January–June 1968

Month (1968)	Potassium (g/day)	Strontium-90 (pCi/day)	Cesium-137 (pCi/day)
January	7.2	21	20
February	6.6	23	40
March	6.3	24	20
April	6.1	23	60
May	NA	NA	NA
June	7.7	31	70

[a] All strontium-89 values were <3 for this period.

117

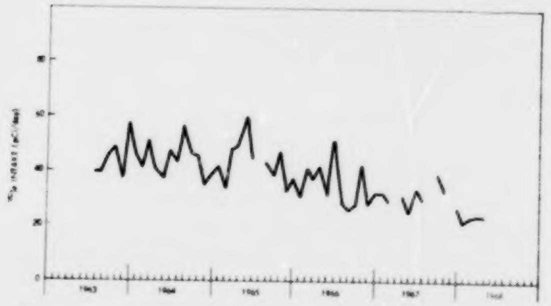

Figure 1. Strontium-90 intake in Connecticut standard diet, 1963–July 1968

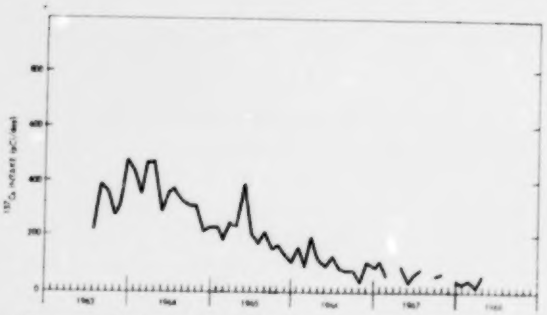

Figure 2. Cesium-137 intake in Connecticut standard diet, 1963–July 1968

REFERENCE

(1) CONNECTICUT STATE DEPARTMENT OF HEALTH. Estimated daily intake of radionuclides in Connecticut standard diet, March 1963–December 1964. Radiol Health Data 6:381–382 (July 1965).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1967	November 1967
July–December 1967	May 1968

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

Water sampling program	Period reported	Last presented
Colorado River Basin	1965–1966	May 1968
Florida	1965–1966	July 1968
Minnesota	July–December 1967	October 1968
New York	June–December 1967	October 1968
Radiostrontium in Tap Water, HASL	July–December 1967	June 1968
Tritium in Surface Water, PHS	1967	October 1968
Washington	July 1966–June 1967	August 1968

---

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.. The limit for unidentified alpha emitters is taken as the limit for radium-226.

REFERENCES

(*1*) U. S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Gross Radioactivity, May 1968, and Strontium-90, July 1966-September 1967, in Surface Waters of the United States

Division of Pollution Surveillance
Federal Water Pollution Control Administration
Department of the Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as part of the Water Pollution Surveillance System currently operated by the Federal Water Pollution Control Administration. Beginning with the establishment of 50 sampling points, this system has been expanded to include 131 stations. These stations are operated jointly with other Federal, State, and local agencies, and with private industries. Samples are taken from surface waters of all major U.S. river basins for physical, chemical, biological, and radiological analyses. The system provides background information necessary for recognizing water quality trends and for determining current and general levels of surface water contamination and early detection of specific situations which may warrant more detailed evaluation. Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

Sampling procedures

The participating agencies collect 1-liter "grab" samples each week and ship them to the Surveillance System Laboratory in Cincinnati. Presently, gross alpha and beta radioactivity determinations are made either on monthly composites of the weekly samples or on each weekly sample. Weekly alpha and beta radio-

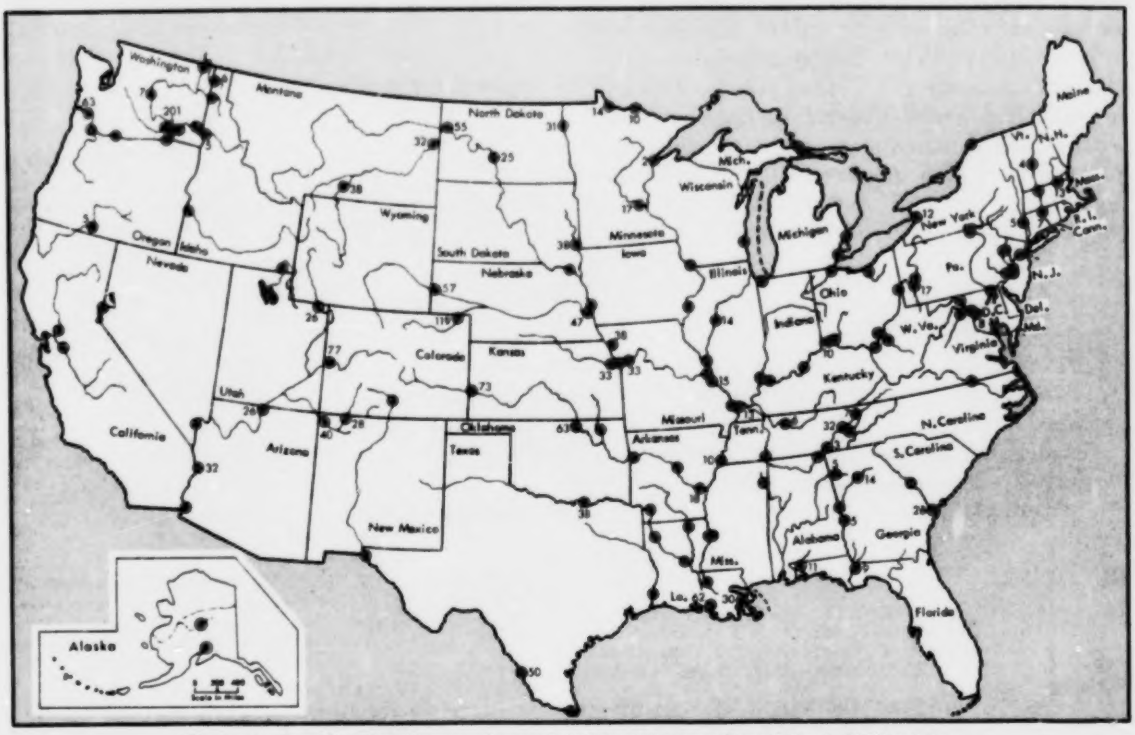
Washington
Montana
North Dakota
Wyoming
South Dakota
Nebraska
Oregon
Idaho
Nevada
Utah
Colorado
Kansas
California
Arizona
New Mexico
Oklahoma
Texas
Minnesota
Iowa
Wisconsin
Mich.
Michigan
Illinois
Indiana
Ohio
Missouri
Arkansas
Kentucky
Tenn.
Miss.
La.
Alabama
Georgia
Florida
S. Carolina
N. Carolina
Virginia
W. Va.
Pa.
New York
N.J.
Del.
Md.
D.C.
Vt.
N.H.
Mass.
R.I.
Conn.
Maine
Alaska
Scale in Miles
63
7
201
5
55
32
31
25
38
57
119
47
26
77
73
26
40
28
32
63
38
50
14
10
17
38
38
33
33
14
15
13
10
10
18
62
30
11
32
14
35
15
28
12
17
5
4
13

Figure 1. Sampling locations and associated total beta radioactivity (pCi/liter) in surface waters, May 1968

activity determinations are scheduled for stations located downstream from known potential sources of radioactive waste. Weekly analyses are conducted at all newly established stations for the first year of operation. Weekly analyses are also scheduled for selected stations in an effort to detect short-term increases in radioactivity from current or recent nuclear tests or events.

Analytical methods

The analytical method used for determining gross alpha and beta radioactivity is described in the twelfth edition of "Standard Methods for the Examination of Water and Wastewater" (*7*). Suspended and dissolved solids are separated by passing the sample through a membrane filter (type HA) with a pore size of 0.45 micron. Planchets are then prepared for counting the dissolved solids (in the filtrate) and the suspended solids (on the charred membrane filter) in an internal proportional counter. Reference sources of U_3O_8 are used for daily checking of the counter.

Normally, samples are counted within 2 weeks following collection or within 1 week after compositing. The decay of radioactivity is followed on each sample for which the first analysis shows unusually high radioactivity. Also, if a recount indicates that the original analysis was questionable, values based on the recount are recorded. All results are reported for the time of counting and are not extrapolated to the date of collection.

Results

Table 1 presents the current preliminary results of the alpha-and beta-particle analysis of United States surface waters. The stations on a river are arranged in the table according to their distance from the headwaters. The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pCi/liter. When all samples have 0 pCi/liter, the mean is reported as 0; when the calculated mean in between 0 and 0.5, the mean is reported as <1 pCi/liter.

A geographical perspective of the radioactivity in surface water is obtained from the numbers printed near the stations shown in figure 1, which gives the average total beta radioactivity in suspended-plus-dissolved solids in raw water collected at each station.

It has been observed that, in water, the natural environmental beta radioactivity is usually several times that of the natural environmental alpha radioactivity. Nuclear installations may contribute additional alpha or beta radioactivity whereas fallout contributes primarily additional beta radioactivity. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes (*9*).

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data and for comment on the data, if needed. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment (*10*). Changes from or toward these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. No discussion of gross radioactivity per gram of dissolved or suspended solids for all stations of the Water Pollution Surveillance System will be attempted at this time. Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high comment will be made.

During May 1968, the following stations showed values of 15 pCi/liter or greater on alpha radioactivity for dissolved solids:

> Arkansas River, Coolidge Kans, Colorado River, Parker Dam, Ariz-Calif; North Platte River, Henry, Nebr; and South Platte River, Julesburg, Colo.

Strontium–90 determinations and results

Beginning in 1959, strontium–90 analyses of the total solids in surface waters were made quarterly on 3-month composites of aliquots from weekly samples. Beginning in November

Table 1. Radioactivity in raw surface waters, May 1968

Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:						
Cedar Hill, N. Mex	6	1	7	22	6	28
Apalachicola River:						
Chattahoochee, Fla	1	0	1	5	4	9
Arkansas River:						
Coolidge, Kans	1	26	27	6	67	73
Ponca City, Okla	5	0	5	38	25	63
Pendleton Ferry, Ark	0	0	0	4	14	18
Atchafalaya River:						
Morgan City, La	10	0	10	54	8	62
Big Horn River:						
Hardin, Mont	2	5	7	9	29	38
Big Sioux River:						
Sioux Falls, S. Dak	1	3	4	7	31	38
Chattahoochee River:						
Atlanta, Ga	2	0	2	9	5	14
Columbus, Ga	1	0	1	3	2	5
Clearwater River:						
Lewiston, Idaho	0	0	0	3	2	5
Clinch River:						
Clinton, Tenn	0	0	0	3	4	7
Kingston, Tenn [a]	1	0	1	2	30	32
Colorado River:						
Loma, Colo	12	5	17	59	18	77
Page, Ariz	0	6	6	1	25	26
Parker Dam, Calif-Ariz	0	15	15	2	30	32
Columbia River:						
Wenatchee, Wash	0	1	1	1	6	7
Pasco, Wash [a]	0	1	1	69	132	201
Clatskanie, Ore	0	0	0	17	46	63
Connecticut River:						
Wilder, Vt	0	0	0	0	4	4
Enfield Dam, Conn	0	0	0	3	4	7
Coosa River:						
Rome, Ga	1	0	1	1	4	5
Cumberland River:						
Cheatham Lock, Tenn	0	0	0	4	2	6
Escambia River:						
Century, Fla	1	0	1	5	6	11
Great Lakes:						
Duluth, Minn	0	0	0	0	2	2
Buffalo, N.Y	0	0	0	1	11	12
Green River:						
Dutch John, Utah	0	3	3	2	24	26
Hudson River:						
Poughkeepsie, N.Y	0	0	0	1	4	5
Illinois River:						
Peoria, Ill	1	1	2	1	13	14
Kansas River:						
DeSoto, Kans	2	3	5	8	25	33
Klamath River:						
Keno, Ore	0	0	0	1	4	5
Merrimack River:						
Lowell, Mass	0	0	0	4	9	13
Mississippi River:						
St. Paul, Minn	0	0	0	2	15	17
E. St. Louis, Ill	2	1	3	9	6	15
W. Memphis, Ark	1	1	2	4	6	10
New Orleans, La	6	0	6	20	10	30
Missouri River:						
Williston, N. Dak	5	3	8	27	28	55
Bismarck, N. Dak	0	3	3	3	22	25
St. Joseph, Mo	3	2	5	10	28	38
Missouri City, Mo	1	3	4	2	31	33
Monongahela River:						
Pittsburgh, Pa	2	0	2	8	9	17
North Platte River:						
Henry, Nebr	3	15	18	10	47	57
Ohio River:						
Cincinnati, Ohio	1	0	1	3	7	10
Cairo, Ill	3	0	3	5	8	13
Pend Oreille River:						
Albeni Falls Dam, Idaho	0	0	0	1	5	6
Platte River:						
Plattsmouth, Nebr	2	4	6	16	31	47
Potomac River:						
Washington, D.C	1	0	1	3	5	8
Rainy River:						
International Falls, Minn	0	0	0	2	8	10
Baudette, Minn	0	0	0	2	12	14
Red River, North:						
Grand Forks, N. Dak	1	2	3	2	29	31
Red River, South:						
Denison, Tex	0	1	1	0	38	38
Rio Grande:						
Laredo, Tex	7	1	8	32	18	50
San Juan River:						
Shiprock, N. Mex	7	1	8	30	10	40
Savannah River:						
Port Wentworth, Ga [a]	0	0	0	6	22	28
South Platte River:						
Julesburg, Colo	4	27	31	11	108	119
Tennessee River:						
Chattanooga, Tenn	0	2	2	0	3	3
Yellowstone River:						
Sidney, Mont	2	3	5	15	17	32
Maximum	12	27	31	69	132	201
Minimum	0	0	0	0	2	2

[a] Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides.

1962, the frequency of analysis was reduced to two quarterly samples per year at each sampling point except at those stations immediately below nuclear installations, where regular quarterly analyses were continued. The method used for determining strontium-90 is a modification of a procedure described by Harley (*8*). Yttrium-90 together with a yttrium carrier is precipitated as yttrium oxalate and the latter is washed, dried, weighted, and counted in a low-background, anticoincidence, end-window proportional counter.

Table 2 presents the results of quarterly analyses of strontium-90 concentrations in U.S. surface waters for the third and fourth quarters of 1966 and the first, second and third quarters of 1967. The stations are arranged in the table according to their distance from the headwaters.

While there are no standards for strontium-90 radioactivity of total solids in surface waters, the Public Health Service Drinking Water Standards set the limit for strontium-90 concentrations in drinking water at 10 pCi/liter.

Table 2. Quarterly strontium-90 concentrations in surface waters, July–December 1966 and January–September 1967

Station	Average concentrations (pCi/liter)				
	July-Sept 1966	Oct-Dec 1966	Jan-Mar 1967	Apr-June 1967	July-Sept 1967
Allegheny River:					
Pittsburgh, Pa			0.8		1.2
Animas River:					
Cedar Hill, N. Mex	1.4	2.0		1.1	1.0
Apalachicola River:					
Chattahoochee, Fla	1.1	1.5		0.8	
Arkansas River:					
Coolidge, Kans	3.6	4.3		5.2	6.1
Ponca City, Okla			1.1		2.7
Fort Smith, Ark	2.8	3.7		3.0	2.4
Little Rock, Ark					2.4
Pendleton Ferry, Ark					1.7
Atchafalaya River:					
Morgan City, La	2.7	3.6		2.0	
Bear River:					
Preston, Idaho	2.2	1.0	1.1	1.1	
Big Horn River:					
Hardin, Mont					1.6
Big Sioux River:					
Sioux Falls, S. Dak	3.2	2.4		3.3	2.7
Brazos River:					
Arcola, Tex				2.6	3.2
Chattahoochee River:					
Atlanta, Ga					1.3
Columbus, Ga			0.7		1.4
Lanett, Ala	1.4	1.4		0.9	
Chena River:					
Fairbanks, Alaska			1.0		
Clearwater River:					
Lewiston, Idaho	0.7	0.6		0.5	
Clinch River:					
Clinton, Tenn	0.9	0.9	0.7		0.5
Kingston, Tenn	3.6	2.3		5.1	2.2
Colorado River:					
Loma, Colo			0.8		1.8
Page, Ariz	3.0	5.8		3.8	
Boulder City, Nev			2.9		3.0
Parker Dam, Calif/Ariz	4.0	2.6		4.5	
Yuma, Ariz		2.5			2.3
Columbia River:					
Northport, Wash	1.5	1.4		0.8	
Wenatchee, Wash			1.0		2.5
Pasco, Wash		1.8	1.4		2.0
McNary Dam, Ore	1.3	1.4	1.0		1.8
Bonneville, Ore	1.7	1.9		1.9	
Clatskanie, Ore					0.6
Connecticut River:					
Wilder, Vt	1.5	1.2		1.0	
Northfield, Mass				0.8	1.1
Enfield Dam, Conn	1.3	2.6			1.0
Coosa River:					
Rome, Ga			1.0		0.7
Cumberland River:					
Cheatham Lock, Tenn	2.1			0.8	
Cuyahoga River:					
Cleveland, Ohio	4.5	1.2		2.0	
Delaware River:					
Martins Creek, Pa			0.9		0.9
Trenton, N.J	1.1	1.2		0.9	
Philadelphia, Pa			1.1		0.9
Escambia River:					
Century, Fla			0.9		1.0
Great Lakes:					
Duluth, Minn					0.9
Saulte Ste. Marie, Mich	1.1			0.9	
Milwaukee, Wis			1.0		1.4
Gary, Ind	1.6	1.9		1.6	
Port Huron, Mich		2.1	1.3		1.4
Gibraltar, Mich					1.3
Detroit, Mich	1.6	2.2		1.6	
Buffalo, N.Y			2.1		3.3
Green River:					
Dutch John, Utah	4.3	4.4		3.4	
Hudson River:					
Poughkeepsie, N.Y			1.2		1.7
Illinois River:					
Peoria, Ill		1.7	0.9		1.5
Grafton, Ill	1.6		1.0		1.4
Kanawha River:					
Winfield Dam, W. Va	1.0	1.0		0.6	
Kansas River:					
DeSoto, Kans			2.1		3.0
Klamath River:					
Keno, Ore			1.3		1.0
Little Miami River:					
Cincinnati, Ohio	1.6	1.8		1.3	
Maumee River:					
Toledo, Ohio			1.3		1.6
Merrimack River:					
Lowell, Mass	2.0	2.2	1.8		1.6
Mississippi River:					
St. Paul, Minn	4.5			3.3	
Dubuque, Iowa			2.6		3.1
Burlington, Iowa	3.2	2.9		2.0	
E. St. Louis, Ill			1.6		2.1
Cape Girardeau, Mo		3.4		2.3	
W. Memphis, Ark			1.1		1.9
Vicksburg, Miss	2.0	2.6	1.7	2.6	
Delta, La					2.2
New Roads, La			0.9	0.9	
New Orleans, La	2.5	2.3		1.4	
Missouri River:					
Williston, N. Dak			2.2		2.6
Bismarck, N. Dak	2.9	3.3		2.5	
Yankton, S. Dak			2.5		3.1
Omaha, Nebr	3.6	5.0	2.1	3.7	
St. Joseph, Mo					3.2
Kansas City, Kans	4.5	4.2	2.1	3.1	
Missouri City, Mo					3.0
St. Louis, Mo	3.9	3.5		2.4	
Monongahela River:					
Pittsburgh, Pa			1.1		1.5
North Platte River:					
Henry, Nebr			0.5		2.4
Ohio River:					
Toronto, Ohio			2.9		
Addison, Ohio	1.8	2.2		1.5	
Huntington, W. Va			1.1		1.4
Cincinnati, Ohio	2.0	1.2		1.2	
Louisville, Ky			1.5		1.0
Evansville, Ind	1.5	2.1		1.3	
Cairo, Ill			1.1		1.8
Ouachita River:					
Bastrop, La	2.6	2.5		2.0	
Pend Oreille River:					
Albeni Falls Dam, Idaho			1.2		
Platte River:					
Plattsmouth, Nebr	2.8	2.4		2.6	
Potomac River:					
Williamsport, Md			0.4		0.9
Great Falls, Md	1.1	2.3		1.1	
Washington, D.C	1.4	1.3		0.6	
Rainy River:					
Baudette, Minn			1.2		4.1
International Falls, Minn			3.8		3.0
Red River, North:					
Grand Forks, N. Dak	8.6		3.7	4.1	4.5
Red River, South:					
Denison, Tex	6.7	3.7	3.9		4.1
Index, Ark				2.8	
Bossier City, La		2.5	1.1	1.2	2.8
Alexandria, La			2.6		3.4
Rio Grande:					
Alamosa, Colo			1.3		0.6
El Paso, Tex	3.3	0.4		0.2	
Laredo, Tex			0.6		6.0
Brownsville, Tex		0.4	1.6		
Roanoke River:					
John H. Kerr Resr/Dam, Va			0.4		1.3
Sabine River:					
Ruliff, Tex	3.1		1.9		
Sacramento River:					
Greens Landing, Calif	0.9		0.6		0.7
St. Lawrence River:					
Massena, N.Y	2.1		1.6	1.8	
San Juan River:					
Shiprock, N. Mex					3.2
Savannah River:					
North Augusta, S. C	1.4	2.1		1.1	
Port Wentworth, Ga	1.9	2.5	1.0		1.5
Schuylkill River:					
Philadelphia, Pa	1.3	1.3		1.4	
Shenandoah River:					
Berryville, Va			0.4		0.4
Ship Creek:					
Anchorage, Alaska	0.5			0.4	

Table 2. Quarterly strontium-90 concentrations in surface waters, July-December 1966 and January-September 1967—Continued

Station	Average concentrations (pCi/liter)				
	July-Sept 1966	Oct-Dec 1966	Jan-Mar 1967	Apr-June 1967	July-Sept 1967
Snake River:					
Ice Harbor Dam, Wash	0.8	1.0		0.6	
Wawawai, Wash			0.5		1.3
Payette, Idaho			0.4		
South Platte River:					
Julesburg, Colo			1.4		1.7
Spokane River:					
Post Falls Dam, Idaho	0.7				
Susquehanna River:					
Sayre, Pa	2.0	1.2		0.9	
Conowingo, Md			1.1		1.2
Tennessee River:					
Lenoir City, Tenn	1.2		0.7		
Chattanooga, Tenn			1.1		
Pickwick Landing, Tenn	1.4	1.3		0.8	1.2
Tombigbee River:					
Columbus, Miss	1.7	1.3		1.3	
Truckee River:					
Farad, Calif			1.0		0.3
Wabash River:					
New Harmony, Ind			1.8		
Willamette River:					
Portland, Ore			0.3		0.9
Yakima River:					
Richland, Wash	0.6	0.3		0.4	
Yellowstone River:					
Sidney, Mont	3.7	1.7		2.6	
Maximum	8.6	5.8	3.9	5.1	6.1
Minimum	0.5	0.3	0.3	0.2	0.4
Median	1.85	2.10	1.10	1.55	1.65
Average	2.30	2.12	1.47	1.76	1.98

During July–December 1966 and January–September 1967, this standard was not reached. Comparison between the quarters is not feasible at all sampling locations due to fluctuations in sampling frequencies. Comparisons with results prior to October 1964 should take into consideration an instrument recalibration which resulted in a lowering of strontium–90 values by 15 percent (*11*).

Although Grand Forks, N. Dak., on the Red River has shown maximum quarterly values of strontium–90 in past years, the current quarterly levels for 1967 have shown a decline. On the other hand, the levels at Kingston, Tenn., on the Clinch River below Oak Ridge showed an unusual value in strontium–90 during April–June 1967. An individual strontium–90 determination on a single sample collected May 22, 1967, gave a result of 17.5 pCi/liter. This condition was temporary since the gross beta radioactivity on both the May 22 sample and the following samples contained 70 pCi/liter and 21 pCi/liter, respectively. From June through November of 1967, gross beta radioactivity at this station has been at normally low levels. One value of 44 pCi/liter of gross beta radioactivity was detected in December 1967. Values since that time were low.

REFERENCES

(*1*) DIVISION OF WATER SUPPLY AND POLLUTION CONTROL, PUBLIC HEALTH SERVICE. National Water quality network annual compilation of data. PHS Publication No. 663, 1958 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*2*) Ibid., 1959 Edition.

(*3*) Ibid., 1960 Edition.

(*4*) Ibid., 1961 Edition.

(*5*) Ibid., 1962 Edition.

(*6*) DIVISION OF WATER SUPPLY AND POLLUTION CONTROL, PUBLIC HEALTH SERVICE. Water pollution surveillance system, annual compilation of data, PHS Publication No. 663 (Revised) 1963 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*7*) AMERICAN PUBLIC HEALTH ASSOCIATION: AMERICAN WATER WORKS ASSOCIATION AND WATER POLLUTION CONTROL FEDERATION. Standard methods for the examination of water and wastewater, 11th Edition. New York (1960).

(*8*) HARLEY, J. H. Radiochemical determinations of strontium–90, Health and Safety Laboratory manual of standard procedures, August 1962 Revision. Radiochemistry and Environmental Studies Division, HASL, U.S. Atomic Energy Commission, New York Operations Office (1962).

(*9*) STRAUB, C. P. Significance of radioactivity data. JAWWA 53:704 (June 1961).

(*10*) PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*11*) PUBLIC HEALTH SERVICE. DIVISION OF WATER SUPPLY AN DPOLLUTION CONTROL. Gross radioactivity and strontium–90 in surface waters of the United States, January 1965. Radiol Health Data 5:393–396 (July 1965).

Tritium in Surface Water Network January-June 1968

National Center for Radiological Health
U.S. Public Health Service

The tritium sampling network was established by the Public Health Service in May 1964 to measure and monitor tritium concentrations in major river systems in the United States and to provide surveillance at selected surface water stations downstream from nuclear facilities. The network consists of 10 stations selected from the 131 existing water pollution sampling stations operated by the Federal Water Pollution Control Administration (FWPCA); eight of the stations are located downstream from nuclear facilities and two stations were to establish baseline levels (figure 1). Articles covering the period 1964–1965 (*1*) and 1966 (2) and a data report for 1967 have been published previously in *Radiological Health Data and Reports.*

Monthly composites of weekly samples are collected through the FWPCA and sent to the Southeastern Radiological Health Laboratory for analysis. The analyses are carried out using liquid scintillation counting techniques described by Moghissi et al (*3*). The minimum level of detectability is 0.2 nCi/liter.

Data for the samples collected during the first 6 months of 1968 are shown in table 1. Station averages for this period and the corresponding period of 1967 are also presented in the table. The highest concentration observed during the first 6 months of 1968 was 23.5 nCi/liter (Clinch River - Kingston, Tenn.). The highest 6-month average, 9.6 nCi/liter, was also observed at the Clinch River station. Assuming

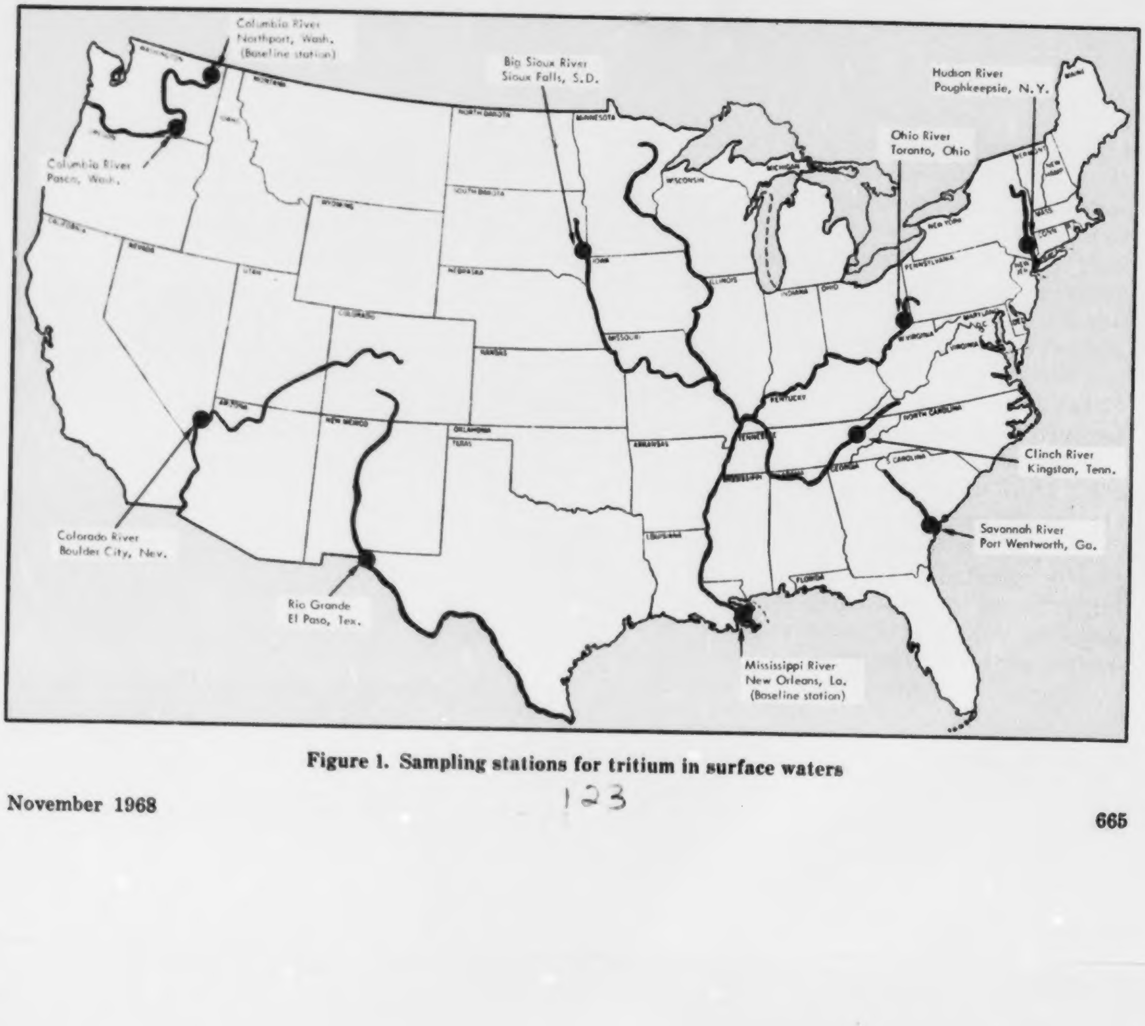
Columbia River
Northport, Wash.
(Baseline station)
Big Sioux River
Sioux Falls, S.D.
Hudson River
Poughkeepsie, N.Y.
Ohio River
Toronto, Ohio
Columbia River
Pasco, Wash.
Clinch River
Kingston, Tenn.
Savannah River
Port Wentworth, Ga.
Colorado River
Boulder City, Nev.
Rio Grande
El Paso, Tex.
Mississippi River
New Orleans, La.
(Baseline station)

Figure 1. Sampling stations for tritium in surface waters

Table 1. Tritium concentration of surface waters, January–June 1968

Collection site	Concentration (nCi/liter)[a]							
	Jan	Feb	Mar	Apr	May	June	Jan-June average[b]	
							1968	1967
Big Sioux River: Sioux Falls, S. Dak	0.6 ±0.2	0.6 ±0.2	0.5±0.2	[c]0.2 ±0.2	0.6 ±0.2	0.4 ±0.2	0.4	1.2
Clinch River: Kingston, Tenn	2.8 ±0.3	2.6 ±0.3	4.6±0.4	14.4 ±0.7	23.5 ±0.9	NS	9.6	4.4
Colorado River: Boulder City, Nev	2.3 ±0.3	2.2 ±0.2	3.6±0.3	2.0 ±0.2	1.7 ±0.2	2.1 ±0.3	2.3	2.6
Columbia River: Northport, Wash [d]	NS	NS	NS	NS	NS	NS	—	1.7
Columbia River: Pasco, Wash	NS	0.8 ±0.2	1.0±0.2	1.4 ±0.2	0.8 ±0.2	0.8 ±0.2	1.0	1.5
Hudson River: Poughkeepsie, N.Y	0.4 ±0.2	0.4 ±0.2	1.6±0.2	0.5 ±0.2	0.4 ±0.2	[b]0.2 ±0.2	.6	1.1
Mississippi River: New Orleans, La [d]	[b]0.2 ±0.2	[b]0.2 ±0.2	0.9±0.2	[b]0.2 ±0.2	[b]0.2 ±0.2	[b]0.2 ±0.2	.2	.7
Ohio River: Wheeling, W. Va	NS	0.7 ±0.2	NS	NS	NS	0.3 ±0.2	.5	.8
Rio Grande: El Paso, Tex	NS	NS	NS	NS	NS	NS	—	.7
Savannah River: Port Wentworth, Ga	3.8 ±0.3	9.4 ±0.5	9.4±0.5	6.5 ±0.4	12.0 ±0.7	3.7 ±0.5	7.5	8.4

[a] The error reported is the two-sigma error at the 95-percent confidence level.
[b] Values less than or equal to the minimum level of detectability (0.2 nCi/liter) were averaged as zero.
[c] Values are not statistically significant at the 95-percent confidence level.
[d] Baseline station.
NS, no sample.

that the specific activity of tritium in the body is essentially the same as that in the surface water, this average concentration corresponds to an estimated whole-body dose[1] of 1.6 mrem/year; or in terms of Federal Radiation Council guidance, approximately 1 percent of the Radiation Protection Guide (170 mrem/year) for an average dose to a suitable sample of the exposed population (*4*). With the exception of the Clinch River station, all stations showed lower 6-month averages for this January-June collection period than for the comparable period in 1967. The 6-month average for the Clinch River station increased from 4.4 to 9.6 nCi/liter.

The samples for the Ohio River station, previously collected at Toronto, Ohio, are now being collected at Wheeling, W. Va. The new sampling location is approximately 50-miles downstream from Toronto.

REFERENCES

(*1*) CHESNUTT, M. W., J. C. DROBINSKI, JR., and R. H. GORRIE. Tritium in surface waters, 1964–1965. Radiol Health Data Rep 7:377–380 (1966).

(*2*) MOGHISSI, A. A., and C. R. PORTER. Tritium in surface waters in the United States, 1966. Radiol Health Data Rep 9:337–339 (1968).

(*3*) MOGHISSI, A. A., H. L. KELLEY, J. E. REGNIER, and M. W. CARTER. Low level tritium counting by means of liquid scintillation. (To be published).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1 (May 13, 1960). Superintendent of Documents, U.S. Government Printing Office. Washington, D.C. 20402.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–December 1967	October 1968

---

[1] Development of the calculations to obtain this dose may be found in reference 2.

Radioactivity in California Waters[1] July-December 1967

Bureau of Radiological Health
State of California
Department of Public Health

Gross beta radioactivity in California domestic waters is monitored by the State of California's Bureau of Radiological Health. The importance of this program in the State's environmental surveillance activities stems from the fact that most of California's domestic water supplies are of surface origin.

Radioactivity in such water supplies consists of the natural radioactivity in surface streams, radioactivity added by the discharge of sewage or by industrial waste effluents, and radioactivity from fallout, particularly fallout into open terminal or distribution reservoirs. Present efforts consist of sampling raw and treated surface waters and well waters. It should be noted that except for large metropolitan water supplies, raw water sampling is being phased out and treated water sampling being substi-

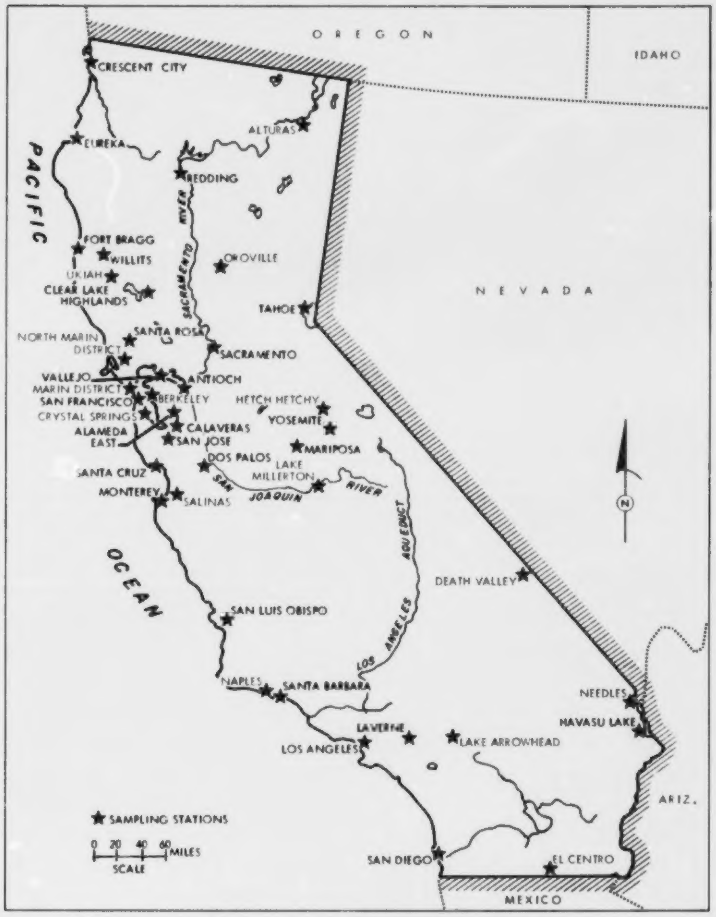
OREGON
IDAHO
NEVADA
PACIFIC
OCEAN
CRESCENT CITY
ALTURAS
EUREKA
REDDING
SACRAMENTO RIVER
FORT BRAGG
WILLITS
OROVILLE
UKIAH
CLEAR LAKE HIGHLANDS
TAHOE
NORTH MARIN DISTRICT
SANTA ROSA
SACRAMENTO
VALLEJO
ANTIOCH
MARIN DISTRICT
SAN FRANCISCO
BERKELEY
HETCH HETCHY
YOSEMITE
CRYSTAL SPRINGS
CALAVERAS
ALAMEDA EAST
SAN JOSE
MARIPOSA
DOS PALOS
LAKE MILLERTON
SANTA CRUZ
SAN JOAQUIN RIVER
MONTEREY
SALINAS
LOS ANGELES AQUEDUCT
DEATH VALLEY
N
SAN LUIS OBISPO
NAPLES
SANTA BARBARA
NEEDLES
HAVASU LAKE
LAVERNE
LAKE ARROWHEAD
LOS ANGELES
ARIZ.
SAMPLING STATIONS
0 20 40 60 MILES
SCALE
SAN DIEGO
EL CENTRO
MEXICO

Figure 1. California surface water sampling stations

---

[1] Data from January and April 1968 issues of Radiological Health News, State of California, Department of Public Health, Bureau of Radiological Health, 2151 Berkeley Way, Berkeley, Calif. 94704.

Table 1. Gross beta radioactivity in California domestic waters, July–December 1967

Sampling station	Quality	Concentration (pCi/liter)					
		July	August	September	October	November	December
Alturas	Well	NS	NS	NS	[a] 5	ND	[a] 16
Antioch	Treated	8	ND	ND	40	[a] 1	[a] 17
Berkeley	Treated	ND	[a] 8	[a] 6	41	[a] 23	[a] 3
Clearlake Highlands	Treated	ND	[a] 10	ND	ND	ND	59
Crescent City	Well	30	ND	[a] 9	44	[a] 11	[a] 1
Death Valley	Treated	63	[a] 20	[a] 6	29	ND	[a] 18
Dos Palos	Treated	[a] 14	[a] 13	[a] 8	ND	ND	[a] 4
Eureka	Raw	[a] 1	[a] 14	[a] 8	ND	[a] 2	[a] 2
	Treated	NS	ND	ND	[a] 16	ND	[a] 2
Fort Bragg	Treated	NS	NS	NS	[a] 2	28	NS
Lake Arrowhead	Treated	[a] 12	NS	NS	[a] 15	[a] 20	NS
Lake Millerton	Raw	[a] 11	[a] 17	24	ND	[a] 3	[a] 15
Los Angeles	Raw	ND	[a] 35	[a] 11	[a] 4	32	NS
Marin Municipal Water District	Treated	[a] 13	NS	NS	NS	NS	NS
Mariposa	Treated	[a] 7	NS	NS	NS	NS	NS
Metropolitan Water District South Calif:							
Weymouth Plant	Treated	ND	[a] 10	[a] 10	[a] 20	ND	38
Monterey	Treated	ND	[a] 3	NS	NS	[a] 2	36
Napa	Treated	ND	[a] 7	[a] 6	ND	ND	32
Needles	Well	[a] 8	[a] 2	NS	ND	22	272
North Marin Water District	Treated	[a] 4	ND	ND	ND	56	27
	Raw	[a] 3	ND	[a] 5	[a] 23	[a] 19	ND
	Sludge [b]	ND	ND	[a] 11	ND	[a] 18	ND
Oroville:							
Wyandotte Irrigation District	Treated	NS	[a] 7	ND	NS	ND	NS
Pleasanton	Well	ND	[a] 13	ND	[a] 13	ND	[a] 2
Redding	Treated	NS	ND	ND	NS	[a] 6	NS
Sacramento:							
American River	Treated	NS	ND	[a] 1	ND	[a] 6	NS
Sacramento River	Treated	NS	ND	[a] 18	22	[a] 10	NS
Salinas	Well	[a] 8	NS	NS	NS	NS	NS
San Diego	Raw	ND	[a] 4	[a] 20	[a] 24	[a] 13	42
	Treated	[a] 18	ND	[a] 14	ND	[a] 23	[a] 4
San Francisco:							
Water Department	Raw	ND	[a] 9	ND	[a] 10	ND	2
Alameda East	Raw	NS	ND	ND	ND	ND	27
Brightside Weir	Raw	NS	ND	[a] 11	ND	[a] 6	[a] 10
Calavaras Reservoir	Raw	NS	[a] 8	ND	ND	[a] 5	[a] 9
Crystal Springs	Raw	NS	[a] 17	NS	NS	NS	NS
Hetch Hetchy	Raw	ND	[a] 11	[a] 11	ND	ND	ND
San Jose	Raw	[a] 6	ND	ND	[a] 9	[a] 5	NS
San Luis Obispo	Treated	NS	NS	[a] 2	ND	ND	37
Santa Barbara	Treated	ND	[a] 9	[a] 18	[a] 10	ND	ND
Santa Cruz	Treated	NS	[a] 3	[a] 6	ND	ND	NS
Santa Rosa	Raw	[a] 8	ND	ND	[a] 10	[a] 4	[a] 13
Scotia	Raw	ND	[a] 13	ND	53	[a] 1	[a] 2
	Treated	NS	[a] 10	[a] 5	ND	[a] 4	32
Tahoe City	Raw	NS	[a] 5	NS	ND	[a] 4	NS
Ukiah	Well	ND	ND	[a] 5	ND	[a] 6	[a] 9
Vallejo:							
Fleming Hill	Raw	44	[a] 9	[a] 1	ND	ND	[a] 12
	Treated	[a] 19	37	[a] 4	39	[a] 4	ND
Swanzy Reservoir	Treated	[a] 4	ND	29	[a] 4	[a] 18	[a] 11
Willits	Treated	NS	[a] 4	[a] 3	ND	[a] 1	[a] 2
Yosemite	Treated	[a] 6	ND	[a] 14	47	[a] 3	NS
Maximum		63	37	29	53	56	272
Minimum		1	2	1	2	1	1

[a] When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported is the best estimate, but is not statistically significant.

[b] Sludge reported in pCi/g (dry weight).

ND, nondetectable.

NS, no sample collected.

tuted or continued. This procedural change is predicated upon sampling water at the point of consumption.

Most of the supplies sampled have, as a source, raw surface waters (figure 1), although a few wells, along with some water supplies that use infiltration galleries, are also sampled.

Monitoring of domestic water supplies is on a continuing basis, since it has not been possible to forecast levels of radioactivity in these supplies based upon levels in rain, snow, or surface streams. Under the present sampling schedule, monthly 500 ml samples are collected and the total solids analyzed for alpha and beta radio-

Table 2. Radionuclide concentrations in California surface waters, January–December 1967

Sampling station and date (1967)	Radionuclide concentrations (pCi/liter)						
	Potassium-40	Manganese-54	Strontium-89	Strontium-90	Zirconium-niobium-95	Cesium-137	Radium-226
Antioch:							
January-June	[a] 2	ND	ND	ND	ND	ND	0.03
July-December	1	ND	ND	1	ND	ND	NA
Berkeley:							
January-June	[a] 1	ND	ND	1	ND	ND	ND
July-December	ND	ND	ND	1	ND	ND	.01
Clearlake Highlands:							
January-June	ND	ND	ND	ND	ND	ND	.03
July-December	ND	ND	ND	1	1	ND	.02
CrescentCity:							
July-December	ND	ND	ND	ND	ND	ND	[a] .01
Death Valley:							
January-June	[a] 9	ND	ND	1	[a] 1	ND	[a] .14
July-December	[a] 3	ND	ND	ND	[a] 1	ND	[a] .04
Dos Palos:							
April-September	[a] 1	ND	ND	ND	ND	ND	.09
October-December	[a] 2	[a] 2	ND	[a] 1	[a] 1	ND	[a] .04
El Centro:							
January-June	[a] 3	ND	ND	1	ND	ND	.29
Eureka:							
January-June	[a] 2	ND	ND	ND	ND	ND	.03
July-December	[a] 1	ND	ND	ND	ND	ND	[a] .02
Fort Bragg:							
July-December	ND	ND	ND	ND	ND	ND	.01
Lake Millerton:							
April-August	[a] 2	ND	1	1	ND	ND	.03
September-December	ND	ND	ND	1	ND	ND	ND
Marin Municipal Water District:							
July-December	ND	ND	ND	1	ND	ND	[a] .01
Metropolitan Water District of southern Calif:							
January-June	[a] 3	ND	ND	1	ND	ND	[a] .04
July-December	[a] 5	ND	ND	1	1	ND	[a] .03
Monterey:							
April-August	[a] 2	ND	ND	ND	ND	ND	.11
Napa:							
January-June	[a] 3	ND	ND	ND	ND	ND	.04
July-December	[a] 1	ND	ND	1	ND	ND	[a] .01
Needles:							
January-June	[a] 10	ND	[a] 1	ND	ND	ND	ND
July-December	ND	ND	ND	ND	[a] 1	ND	ND
North Marin Water District:							
January-June	16	1	2	ND	ND	1	ND
July-December	[a] 3	ND	ND	1	ND	ND	.01
Oroville:							
January-June	ND	ND	ND	ND	[a] 1	ND	ND
Pleasanton:							
January-June	[a] 1	ND	2	ND	[a] 1	ND	[a] .02
July-December	NA	ND	ND	2	ND	[a] 1	NA
Redding:							
January-June	ND	ND	ND	ND	ND	ND	[a] .02
July-December	[a] 1	ND	ND	ND	1	ND	[a] .01
Sacramento:							
January-June	[a] 1	ND	ND	ND	ND	ND	[a] .02
July-December	[a] 1	ND	ND	ND	[a] 1	ND	[a] .02
San Diego:							
January-June	5	ND	[a] 1	2	ND	ND	[a] .01
July-December	[a] 2	ND	ND	2	ND	ND	[a] .10
San Francisco:							
January-August	[a] 2	ND	[a] 1	1	ND	ND	.04
San Jose:							
January-June	[a] 1	ND	ND	ND	ND	ND	[a] .01
July-December	[a] 1	ND	ND	ND	[a] 1	ND	[a] .01
Santa Barbara:							
March-August	3	ND	ND	1	ND	ND	ND
Santa Cruz:							
January-June	[a] 2	ND	ND	ND	ND	ND	.04
Santa Rosa:							
July-December	[a] 2	ND	ND	ND	ND	ND	[a] .02
Scotia:							
July-December	[a] 1	ND	ND	ND	ND	ND	[a] .02
Tahoe City:							
January-June	ND	ND	[a] 1	ND	ND	ND	.04
Ukiah:							
May-August	[a] 2	ND	ND	ND	ND	ND	[a] .01
Vallejo:							
January-June	[a] 2	ND	ND	1	ND	ND	[a] .01
July-December	[a] 1	ND	ND	ND	ND	ND	[a] .01
Willits:							
July-December	[a] 1	ND	ND	ND	ND	ND	[a] .01
Yosemite:							
March-August	[a] 1	ND	ND	1	ND	ND	[a] .01
September-December	[a] 1	[a] 2	ND	1	ND	5	[a] .02

Results for cerium-141-144 for all stations were nondetectable during this period except for the values of 1 pCi/liter at Needles and 2 pCi/liter at North Marin Water District for January-June 1967.

[a] When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported is the best available estimate but is not statistically significant.

NA, no analysis.

ND, nondetectable.

125

activity. In addition, 3-liter samples are collected monthly for approximately 6 months and composited for specific radionuclide analysis on a semiannual basis.

Analytical procedures

Radionuclide analyses of water are carried out in the State's Sanitation and Radiation Laboratory. Measurements of alpha and alpha-plus-beta radioactivities are made with a low-background windowless gas-flow proportional counter. Counting methods used follow those recommended by the U.S. Public Health Service (*1*).

Individual samples are evaporated to dryness and the residue ashed at 450°C. The ashed sample is dissolved and transferred to an aluminum planchet for beta-particle counting. Specific radionuclides are determined semiannually on composite samples. Gamma-ray emitting nuclides are determined by gamma-ray spectroscopy and radium and radiostrontium by chemical separation and counting.

Discussion

Table 1 shows the monthly average beta radioactivity in the suspended-plus-dissolved solids in surface water supplies in California from July through December 1967. Following treatment, these waters are used for industrial and domestic purposes. Because alpha radioactivity in water has, in general, been undetectable or very slight, alpha radioactivity analyses are not presented. No increase in radioactivity level of surface water has been observed.

Table 2 shows specific radionuclide concentrations in California surface waters of 1967 by stations.

REFERENCE

(*1*) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclide analyses of environmental samples, R 59-6. Radiological Health Research Activities, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio 45226 (November 16, 1959).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July-December 1966	February 1968
January-June 1967	June 1968

Radioactivity in Kansas Surface Waters, July-December 1967

Kansas State Department of Health
Radiological Health Section

Monitoring of levels of radioactivity in the surface waters of Kansas is done by the Kansas State Department of Health, Radiological Health Section, in cooperation with the Water Data Analysis Section. This surveillance program is important because of both the present and future potential use of Kansas surface waters for domestic, recreational, and industrial purposes.

Liter samples are collected every month at each location shown in figure 1. These samples are analyzed for alpha and beta radioactivity. Radioactivity in these waters consists of the natural radioactivity picked up by flowing streams and percolating ground water, radioactivity from sewage discharge into the streams, and some contribution by industrial waste. The final contributing factor to radioactivity content is fallout, particularly over large expanses of open water, such as reservoirs and lakes.

Analytical procedures

The Radiological and Occupational Health Program does radioactivity analyses using techniques similar to those used in California (*1*).

An appropriate size sample, usually 250 ml, is evaporated in an aluminum planchet and counted after drying in an oven at 100°C and cooling in a desiccator. If much suspended solids are present in the water they are removed by centrifugation before measuring out the sample. Alpha and beta radioactivity counting is done in a gas-flow, windowless internal proportional counter.

Discussion

Table 1 shows the alpha and beta radioactivity in the dissolved solids in Kansas surface waters from July through December 1967.

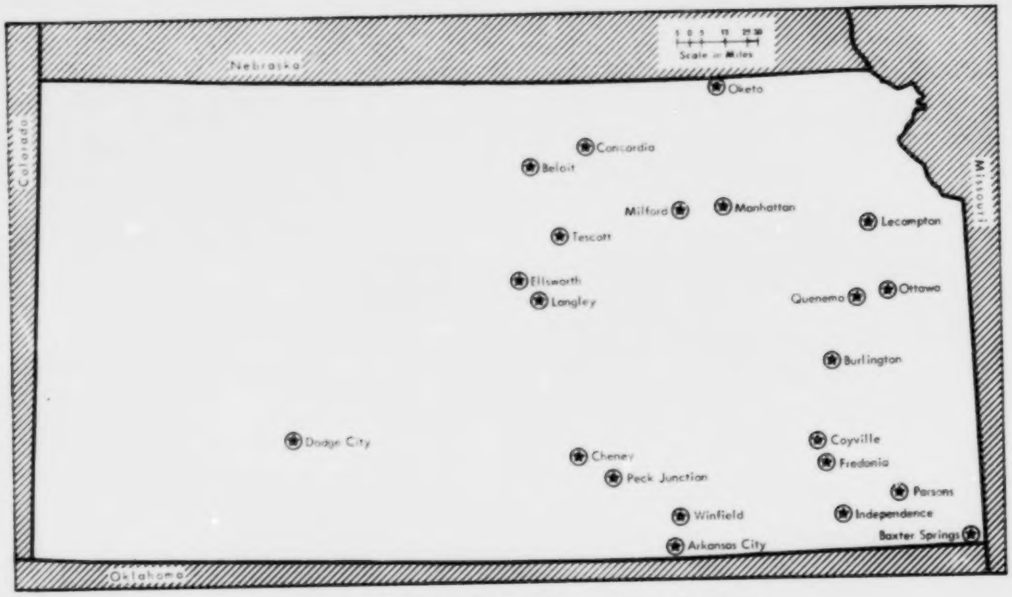
Scale in Miles
Nebraska
Colorado
Missouri
Oklahoma
Oketo
Concordia
Beloit
Milford
Manhattan
Lecompton
Tescott
Ellsworth
Langley
Quenemo
Ottawa
Burlington
Dodge City
Coyville
Fredonia
Cheney
Peck Junction
Parsons
Winfield
Independence
Baxter Springs
Arkansas City

Figure 1. Kansas surface water sampling stations

Table 1. Gross radioactivity in Kansas surface waters, July–December 1967

River and sampling station		Radioactivity concentration (pCi/liter)											
		July		August		September		October		November		December	
		Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta	Alpha	Beta
Arkansas:	Arkansas City	NS	NS	NS	NS	NS	NS	•3	ND	ND	•14	•1	ND
	Dodge City	•39	•20	•9	ND	•2	•37	•23	ND	•12	ND	•66	ND
Big Blue:	Oketo	•1	•14	•2	ND	•2	•12	NS	NS	•4	ND	ND	ND
	Manhattan	•1	•36	•1	•2	ND	ND	NS	NS	•1	•12	ND	•6
Fall:	Fredonia	•1	•10	•3	ND	ND	ND	•1	•8	•1	•2	•5	ND
Kansas:	Lecompton	•1	•15	•3	•28	•3	•7	•1	ND	ND	•12	ND	•5
Marais des Cygnes:	Ottawa	•1	•24	•2	•21	•2	•8	•2	•9	ND	ND	•4	ND
Neosho:	Burlington	•2	•14	NS	NS	NS	NS	NS	NS	ND	ND	•2	ND
	Parsons	•3	•24	•1	•34	ND	•12	NS	NS	•2	NS	•5	•9
Ninnescah:	Cheney	•2	•14	ND	ND	ND	NS	•6	•9	NS	NS	NS	NS
	Peck Junction	•4	ND	16	•17	NS	NS	ND	•9	ND	ND	•5	•23
Republican:	Concordia	13	•26	•4	•6	NS	NS	•2	•2	•2	•17	•1	•10
	Milford	NS	NS	•2	•13	•2	ND	•3	•24	ND	•17	•2	•4
Saline:	Tescott	NS	NS	•3	•18	ND	•12	•2	•13	•15	72	ND	•1
Smoky Hill:	Ellsworth	NS	NS	NS	NS	NS	NS	•5	ND	•6	•8	•13	ND
	Langley	NS	NS	NS	NS	NS	NS	ND	ND	•3	•3	•12	•19
Solomon:	Beloit	•2	•23	ND	•28	•1	•29	NS	NS	NS	NS	NS	NS
Spring:	Baxter Springs	•4	ND	ND	•16	•1	•5	ND	ND	NS	NS	ND	•12
Verdigris:	Coyville	•3	•5	ND	•17	•1	•9	•1	ND	•2	ND	•2	ND
	Independence	•4	ND	ND	ND	ND	ND	•1	•26	•2	ND	ND	ND
Walnut:	Winfield	•2	•9	•4	ND	ND	•7	ND	•20	ND	ND	ND	33

• When the counting rate of the sample is not equal to at least twice the 95 percent error, the value reported is not statistically significant but is the best available estimate.
NS, no sample.
ND, nondetectable.

These waters are used for domestic, industrial, and recreational purposes. The analytical techniques prior to July 1967 were different from those now in use so a valid comparison cannot be made of the present results with those previously obtained.

At the present time there is only one surface water sampling station in western Kansas, at Dodge City. This is partly because of the scarcity of surface water in this region. Plans for the future include the development of at least five sampling points in the western portion of the State.

REFERENCE

(1) STATE OF CALIFORNIA DEPARTMENT OF PUBLIC HEALTH, BUREAU OF RADIOLOGICAL HEALTH. Radioactivity in California waters, July–December 1966. Radiol Health Data Rep 9:108–111 (1968).

128

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports:*

Network	Period	Issue
Fallout Network, HASL	July–December 1967	September 1968
80th Meridian Network, HASL	Calendar year 1965	January 1967

129

1. Radiation Alert Network
July 1968

National Center for Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate National Center for Radiological Health officials by mail or telephone, depending on levels found. Compilation of the daily field estimates is reported elsewhere on a monthly basis (*1*). A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of Radiological Health Data and Reports.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique during July 1968. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting stations.

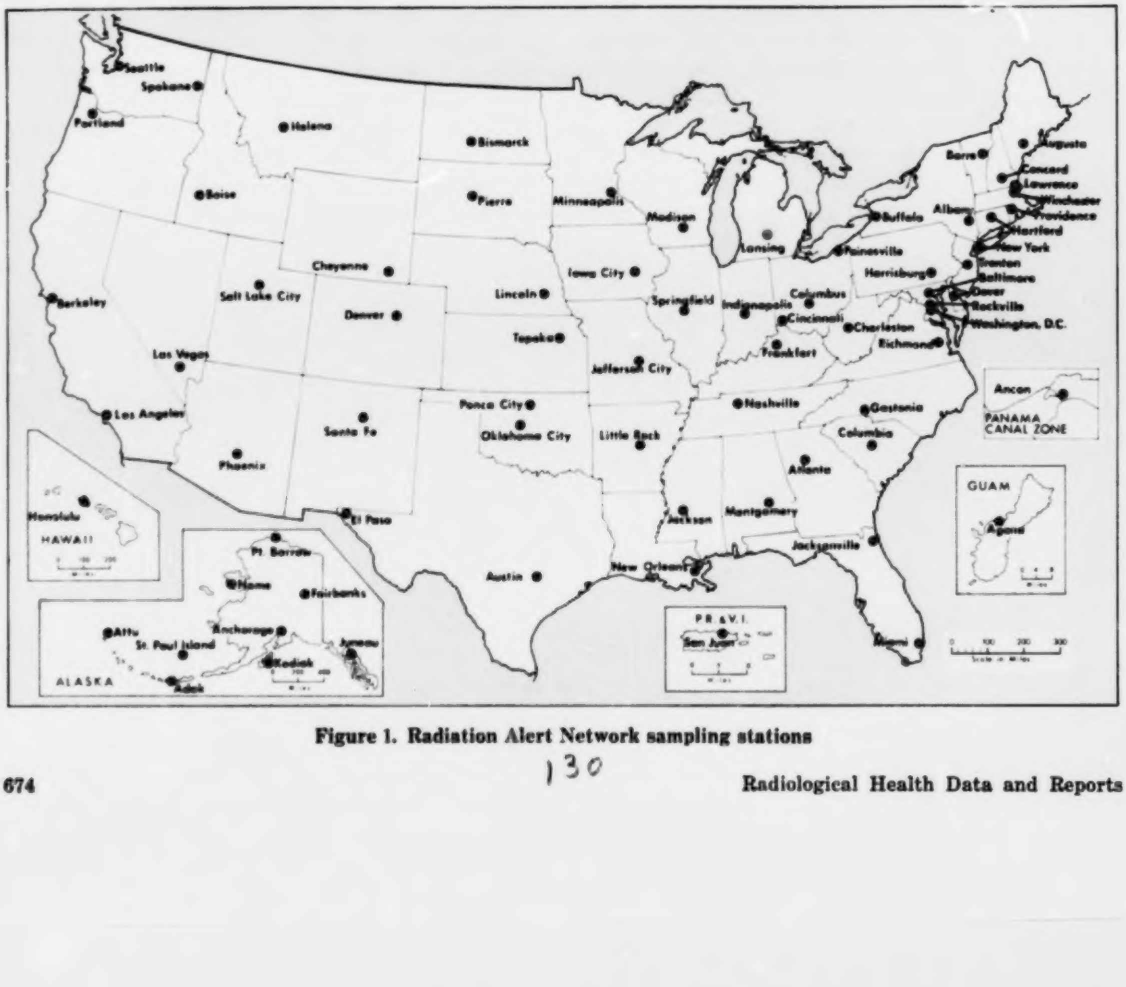
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Madison
Lansing
Barre
Augusta
Concord
Lawrence
Winchester
Providence
Hartford
Buffalo
Albany
Painesville
New York
Trenton
Baltimore
Dover
Rockville
Washington, D.C.
Harrisburg
Cheyenne
Iowa City
Salt Lake City
Lincoln
Berkeley
Denver
Springfield
Indianapolis
Columbus
Cincinnati
Charleston
Richmond
Frankfort
Topeka
Las Vegas
Jefferson City
Ponca City
Nashville
Gastonia
Los Angeles
Santa Fe
Oklahoma City
Little Rock
Columbia
Ancon
PANAMA CANAL ZONE
Phoenix
Atlanta
GUAM
Agana
Honolulu
HAWAII
El Paso
Jackson
Montgomery
Pt. Barrow
Jacksonville
Nome
Fairbanks
Austin
New Orleans
Attu
Anchorage
St. Paul Island
Kodiak
Juneau
Adak
ALASKA
P.R. & V.I.
San Juan
0 100 200 300
Scale in Miles

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, July 1968

Station location		Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Last profile in RHD&R	Precipitation				
							Number of samples	Total depth (mm)	Field estimation of deposition		
		Air	Maximum	Minimum	Average [a]		Pptn		Number of samples	Depth (mm)	Total deposition (nCi/m³)
Ala:	Montgomery	24	6	0	2	Sept 68	8	122	8	122	55
Alaska:	Adak	31	3	1	2	Apr 68	(c)				
	Anchorage	18	0	0	0	Oct 68	3	17	(d)		
	Attu Island	(b)				May 68	(c)				
	Fairbanks	20	7	0	1	Nov 68	8	38	8	38	43
	Juneau	22	0	0	0	Feb 68	11	129	11	129	0
	Kodiak	23	2	0	1	Mar 68	(c)				
	Nome	(b)				July 68	(c)				
	Pt. Barrow	17	4	0	2	June 68	(c)				
	St. Paul Island	9	1	1	1	Aug 68	(c)				
Ariz:	Phoenix	12	5	1	3	Feb 68	(c)				
Ark:	Little Rock	12	3	0	1	Oct 68	1	20	1	20	0
Calif:	Berkeley	22	0	0	0	Mar 68	(c)				
	Los Angeles	5	3	0	2	July 68	(c)				
C. Z:	Ancon	10	1	0	0	Mar 68	(c)				
Colo:	Denver	23	7	0	2	Mar 68	3	15	(d)		
Conn:	Hartford	21	1	0	0	Nov 68	5	39	5	39	6
Del:	Dover	21	2	0	1	Sept 68	(c)				
D. C:	Washington	17	2	0	1	June 68	3	22	3	22	0
Fla:	Jacksonville	20	1	0	1	Oct 68	7	189	7	189	144
	Miami	20	1	0	0	Nov 68	9	203	8	158	0
Ga:	Atlanta	20	2	1	1	Aug 68	8	148	8	148	105
Guam:	Agana	20	1	0	0	Sept 68	(c)				
Hawaii:	Honolulu	31	1	0	1	May 68	(c)				
Idaho:	Boise	20	4	1	3	May 68	(c)				
Ill:	Springfield	2	4	1	2	June 68	1	63	0	0	(e)
Ind:	Indianapolis	20	3	1	2	Aug 68	3	20	3	20	34
Iowa:	Iowa City	22	4	0	2	Mar 68	4	59	4	59	0
Kans:	Topeka	22	4	0	2	Oct 68	8	246	8	246	0
Ky:	Frankfort	2	1	1	1	June 68	1	9	1	9	28
La:	New Orleans	22	1	0	0	June 68	9	151	(d)		
Maine:	Augusta	21	1	0	0	July 68	6	90	6	90	0
Md:	Baltimore	22	2	0	1	Nov 68	3	30	3	30	12
	Rockville	14	2	0	1	May 68	(c)				
Mass:	Lawrence	(b)				Sept 68	5	41	0	0	(e)
	Winchester	21	3	0	1	Apr 68	6	16	6	16	0
Mich:	Lansing	21	7	0	2	May 68	6	72	6	72	209
Minn:	Minneapolis	22	1	0	0	Sept 68	6	145	6	145	53
Miss:	Jackson	21	2	0	1	July 68	4	163	4	163	150
Mo:	Jefferson City	22	4	0	1	Aug 68	5	87	5	87	0
Mont:	Helena	22	6	1	3	Apr 68	3	12	3	12	9
Nebr:	Lincoln	20	6	1	3	Aug 68	8	93	8	93	7
Nev:	Las Vegas	20	6	1	3	Nov 68	(c)				
N. H:	Concord	20	3	1	1	June 68	(c)				
N. J:	Trenton	21	3	0	1	July 68	2	56	2	56	16
N. Mex:	Santa Fe	21	1	0	1	Apr 68	9	62	8	61	15
N. Y:	Albany	20	3	0	1	Aug 68	1	23	1	23	15
	Buffalo	21	4	0	1	Mar 68	(c)				
	New York City	21	2	0	1	Apr 68	(c)				
N. C:	Gastonia	16	6	1	4	Mar 68	3	31	(d)		
N. Dak:	Bismark	22	4	0	1	June 68	3	12	3	12	0
Ohio:	Cincinnati	(b)				Sept 68	(c)				
	Columbus	15	3	0	1	July 68	5	49	4	45	0
	Painesville	22	2	0	1	Nov 68	8	99	8	99	11
Okla:	Oklahoma City	22	4	0	1	May 68	3	18	3	18	6
	Ponca City	24	4	0	2	Nov 68	3	54	3	54	
Ore:	Portland	21	3	0	0	Aug 68	3	17	3	17	
Pa:	Harrisburg	7	2	1	2	Aug 68	(c)				
P. R:	San Juan	(b)				July 68	(c)				
R. I:	Providence	9	2	0	1	May 68	2	21	2	21	4
S. C:	Columbia	22	2	0	1	Apr 68	8	242	7	236	29
S. Dak:	Pierre	15	8	1	3	Feb 68	(c)				
Tenn:	Nashville	16	2	0	1	May 68	6	143	6	143	4
Tex:	Austin	21	5	0	3	Sept 68	4	84	(d)		
	El Paso	21	10	1	2	June 68	(c)				
Utah:	Salt Lake City	29	2	1	1	July 68	1	3	1	3	2
Vt:	Barre	14	2	1	1	Oct 68	7	94	7	94	0
Va:	Richmond	17	1	0	1	Oct 68	3	62	3	62	32
Wash:	Seattle	20	0	0	0	Oct 68	3	11	(d)		
	Spokane	22	4	0	2	Sept 68	(c)				
W. Va:	Charleston	19	3	0	1	Apr 68	9	150	9	150	23
Wis:	Madison	23	1	0	1	Oct 68	7	84	7	84	55
Wyo:	Cheyenne	22	3	1	1	Nov 68	3	25	3	25	32
Network summary		1,275	10	0	1		3	75	5	78	27

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] Indicates no report received. (Air samples showing no field estimate are ignored.)
[c] Indicates no precipatation sample collected.
[d] Indicates that the station is part of the plutonium in precipitation network. No gross beta measurements are done.
[e] Samples were collected but no field estimates were reported.

131

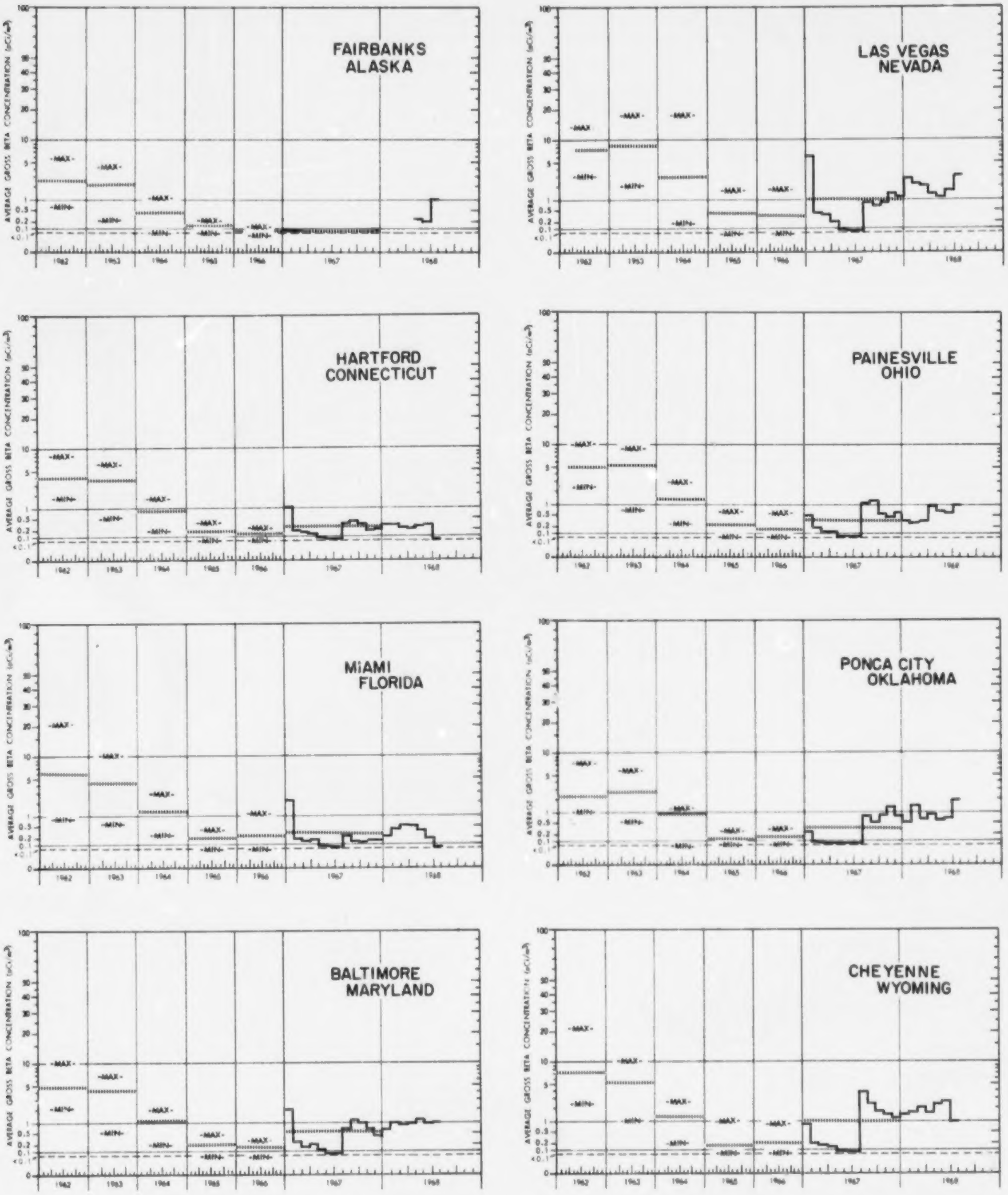

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1962–July 1968

2. Canadian Air and Precipitation Monitoring Program,[1] July 1968

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meterological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*2–6*).

A summary of the sampling procedures and methods of analysis was presented in the October 1968 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for July 1968 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, July 1968

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentrations (pCi/liter)	Total deposition (nCi/m²)
Calgary	31	0.4	0.0	0.2	26	1.7
Coral Harbour	23	.1	.0	.0	32	3.4
Edmonton	31	.3	.0	.2	109	6.4
Ft. Churchill	31	.2	.0	.1	71	3.7
Ft. William	31	.3	.0	.1	58	9.8
Fredericton	30	.3	.0	.2	73	2.1
Goose Bay	31	.2	.0	.2	65	8.2
Halifax	30	.3	.1	.2	143	2.1
Inuvik	31	.3	.0	.1	350	1.6
Montreal	30	.4	.1	.2	NS	NS
Moosonee	31	.3	.0	.2	9	1.4
Ottawa	31	.3	.0	.2	91	5.3
Quebec	9	.1	.0	.1	71	4.7
Regina	31	.4	.0	.2	226	6.5
Resolute	27	.1	.0	.0	13	.1
St. John's, Nfld	31	.3	.0	.1	51	3.2
Saskatoon	31	.4	.0	.1	86	9.5
Saulte Ste Marie	28	.3	.0	.2	170	10.8
Toronto	31	.4	.0	.2	14	.7
Vancouver	31	.2	.0	.1	150	4.0
Whitehorse	31	.2	.0	.1	168	5.3
Windsor	31	.3	.0	.2	37	4.9
Winnipeg	31	.3	.0	.2	49	7.1
Yellowknife	31	.2	.0	.1	208	2.5
Network summary	704	0.4	0.0	0.1	99	4.6

NS, no sample.

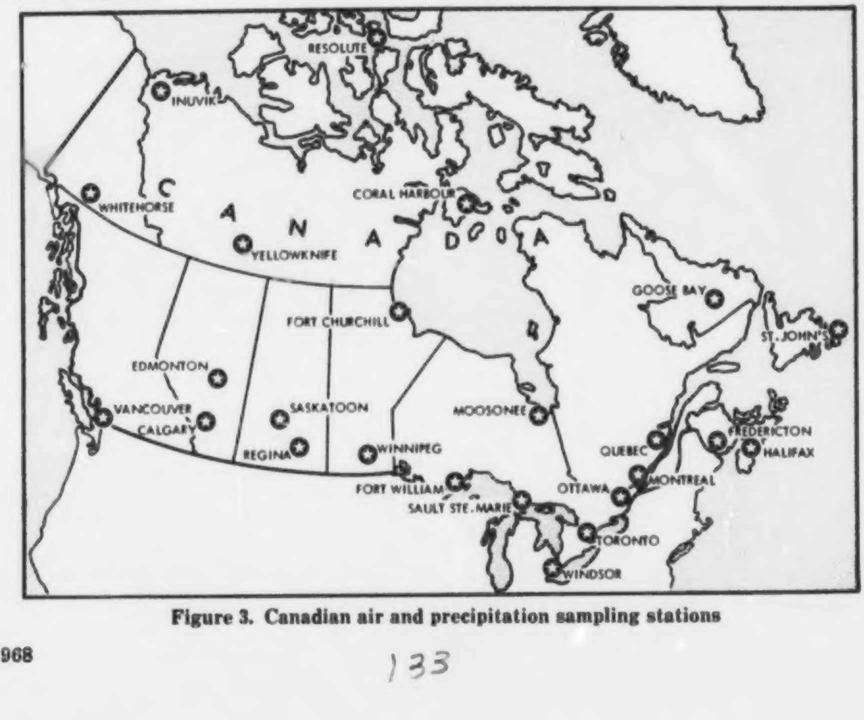
RESOLUTE
INUVIK
C
A
N
A
D
A
WHITEHORSE
CORAL HARBOUR
YELLOWKNIFE
GOOSE BAY
FORT CHURCHILL
ST. JOHN'S
EDMONTON
SASKATOON
VANCOUVER
CALGARY
REGINA
WINNIPEG
MOOSONEE
QUEBEC
FREDERICTON
HALIFAX
MONTREAL
OTTAWA
FORT WILLIAM
SAULT STE. MARIE
TORONTO
WINDSOR

Figure 3. Canadian air and precipitation sampling stations

---

[1] Prepared from information and data in the August 1968 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

3. Pan American Air Sampling Program July 1968

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling locations are shown in figure 4. It should be noted that a new sampling station has been established in Georgetown, Guyana, bringing the total number of participating countries to ten. Analytical techniques were described in the January 1968 *Radiological Health Data and Reports.* The July 1968 air monitoring results from the participating countries are given in table 3. A noticeable increase in the monthly average concentration of gross beta radioactivity was seen in La Paz, Bolivia; Santiago, Chile; and to a lesser extent in Guayaquil, Ecuador. Listed in table 5 are the samples from these stations in which fresh fission products were identified.

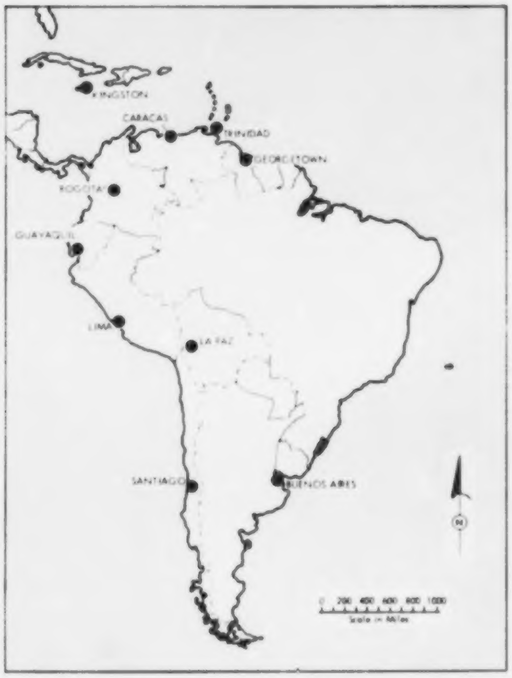

Figure 4. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, July 1968

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average ᵃ
Argentina:	Buenos Aires	7	0.06	0.01	0.03
Bolivia:	La Paz	13	9.81	.03	2.85
Chile:	Santiago	29	3.87	.01	.31
Colombia:	Bogota	16	.09	.01	.03
Ecuador:	Guayaquil	25	.54	.01	.09
Guyana:	Georgetown	2	.13	.09	.11
Jamaica:	Kingston	16	.12	.03	.09
Lima:	Peru	15	.06	.01	.03
Venezuela:	Caracas	20	.57	.01	.12
West Indies:	Trinidad	20	.16	.01	.07
Pan American summary		163	9.81	0.01	0.34

ᵃ The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

Table 4. PAHO air samples in which fresh fission products were identified by gamma spectroscopy

Location		Date (1968)	
Ecuador:	Guayaquil	July	30
Bolivia:	La Paz	July	15 17 18 22 25 26 29 30
Chile:	Santiago	July	26 27 28 29

REFERENCES

(*1*) PUBLIC HEALTH SERVICE. Environmental Radiation Surveillance Report. National Center for Radiological Health, Standards and Intelligence Branch, Rockville, Md. 20852 (Distribution by official request).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW-RP-3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*3*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW-RP-4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*4*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW-RP-5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*5*) BEALE, J., and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD-11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*6*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD-21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Summary of Natural Environmental Gamma Radiation Using a Calibrated Portable Scintillation Counter[1]

National Center for Radiological Health

A portable gamma scintillation counter (PGSC) for field use was developed by the National Center for Radiological Health (*4*) for use in an epidemiological study (*1*). This instrument was calibrated with a highly sensitive muscle equivalent ionization chamber, whose readings convert directly to μrad/hr for 6mm muscle depth at 5 feet above the ground (*2*). The ionization chamber required at least 2 hours for a set of readings at one site, whereas the portable unit requires only 2 minutes per reading. The PGSC uses a 2-inch NaI(Tl) crystal, weighs 12 pounds, is contained within an attaché case, and provides an automatic timer and a digital read-out in counts-per-minutes (cpm). Extensive calibration runs, which paired PGSC and ionization chamber reading under normal environmental background radiation conditions were made during development, field testing and actual field measurements (*3*). These showed that the standard error using the PGSC was 0.35 μrad/hr and the readings were within 4 percent of the ionization chamber readings 95 percent of the time. A bivariate linear function (*4*) was used to convert the PGSC values in cpm to equivalent ionization chamber readings in μrad/hr. An altitude correction was included in this formula to adjust for the decreased sensitivity of the crystal to high energy cosmic radiation which increases at higher elevations. Using the PGSC units, readings were taken over grass or soil in populated areas. Six different PGSC units were used and these were periodically intercalibrated in a round-robin procedure. The sensitivity of the PGSC units was adjusted to give a consistent reading, using a 3 μCi cadmium–109 source, between readings. Simultaneous measurements which were later used to calibrate the PGSC, were made with the ionization chamber and a PGSC at one or two sites in each town.

The data presented in this report were obtained during three separate periods and the precision is in part indicated by the number of readings per town. Phase 1 included 4,624 measurements in 53 towns in Michigan, Minnesota, and Colorado made between October and

---

[1] Written by Mr. S. G. Levin, PSP, NCRH; Mr. R. K. Stoms, Mr. E. Kuerze, and Mr. W. Huskisson, Instrument Development Unit, Electronic Products Radiation Lab, TSB, NCRH, Cincinnati, Ohio 45226.

135

December 1965 at 0.2 mile intervals and provide average dose rates for the selected towns. A more detailed description of this study and an indication of the variability of the readings is presented elsewhere (*3*). Phase 2 measurements constituted a broad survey of 1,131 towns in 19 east coast States made in the summer of 1966. One to thirty measurements were made in each town, depending upon size, generally in the vicinity of a highway, but away from areas of disturbed soil or other man-made surfaces, in an attempt to locate high natural background radiation areas. The PGSC units were calibrated with the ionization chamber in only a few towns during this 12-week survey. Phase 3 measurements were made in 114 towns in Illinois and Iowa to complement a previous epidemiological study (*5*) of the possible effects of radium in well water. This phase was conducted much as that of phase 2, and 4 to 16 readings per town were made between October and December 1966.

Interpretation

The towns in this study were not randomly selected, nor were they selected in a manner such that they would be considered representative of the States of the nation as a whole. In each phase the number and location of the sites of the measurements were determined to best accomplish the objectives of the specific studies.

Figure 1 shows the sites where one or more environmental radiation dose rate measurements were made. It was not possible to make contour lines showing background radiation levels because the measurements were not spaced with this in mind. Table 1 presents the average values for each town where measurements were made. Average values by States are not presented because the measurements made at the various sites in a State would not necessarily represent the State as a whole.

The average dose rate ranged from 5.1 μrad/hr east of Facil, Fla., to 14.6 μrad/hr in Fort Morgan, Colo. The values within a State, and very often within several adjacent States, were relatively uniform with occasional high values in the vicinity of phosphate mines, mine tailings, etc. The coastal areas of Florda and North Carolina generally had low background levels (5–7 μrad/hr); eastern and central States were intermediate with 7 to 12 μrad/hr and the Rocky Mountain areas measured were in the 11 to 15 μrad/hr range.

The data contained in this report provide useful estimates of the outdoor natural background radiation levels in certain populated areas. Since other studies (*6*) have shown that the indoor levels are highly correlated with outdoor levels but are on the average 0.7 as high, inferences about population exposure are possible in those areas covered by the study.

Summary and conclusions

Environmental radiation dose rate measurements which include the contribution from terrestrial and cosmic components were obtained using a portable gamma scintillation counter, which was calibrated with a muscle-equivalent ionization chamber. Measurements were made in 1,298 towns of 24 states in areas where people live and work.

These data may be used to calculate genetically significant doses if other relative data are obtained, such as estimates of the number of persons represented by the measurements, the relative amount of time that individuals are exposed indoors and outdoors, the variation of the background radiation as a function of time, and the relative amount of time people spend outside of the specific area.

REFERENCES

(*1*) GULLEN, W. H., L. M. SCHUMAN, N. J. PETERSEN, and B. J. FRANCIS. Validity of characterization of urban places according to reported congenital malformation rates. J Chron Dis 20:747–757 (1967).

(*2*) KASTNER, J. F., R. SHONKA, and J. E. ROSE. A Muscle-equivalent Environmental Radiation Meter of Extreme Sensitivity. The Natural Radiation Environment, University of Chicago Press (1964) pp. 655–660.

(*3*) LEVIN, S. G. and R. K. STOMS. Natural background gamma radiation dose rate measurements in Michigan, Colorado and Minnesota. To be published, Amer J Public Health.

(*4*) STOMS, R. K. and S. G. LEVIN. A portable gamma-scintillation counter for field measurement of background gamma radiation. (To be published).

(*5*) PETERSEN, N. J., L. D. SAMUELS, M. S. LUCAS, and S. P. ABRAHAMS. An epidemiologic approach to low-level radium-226 exposure. Public Health Rep 81:805–814 (September 1966).

(*6*) LOWDER, W. M., A. SEGALL, and W. J. CONDON. Environmental Radiation Survey in Northern New England. The Natural Radiation Environment, University of Chicago Press (1964) pp. 907–917.

136

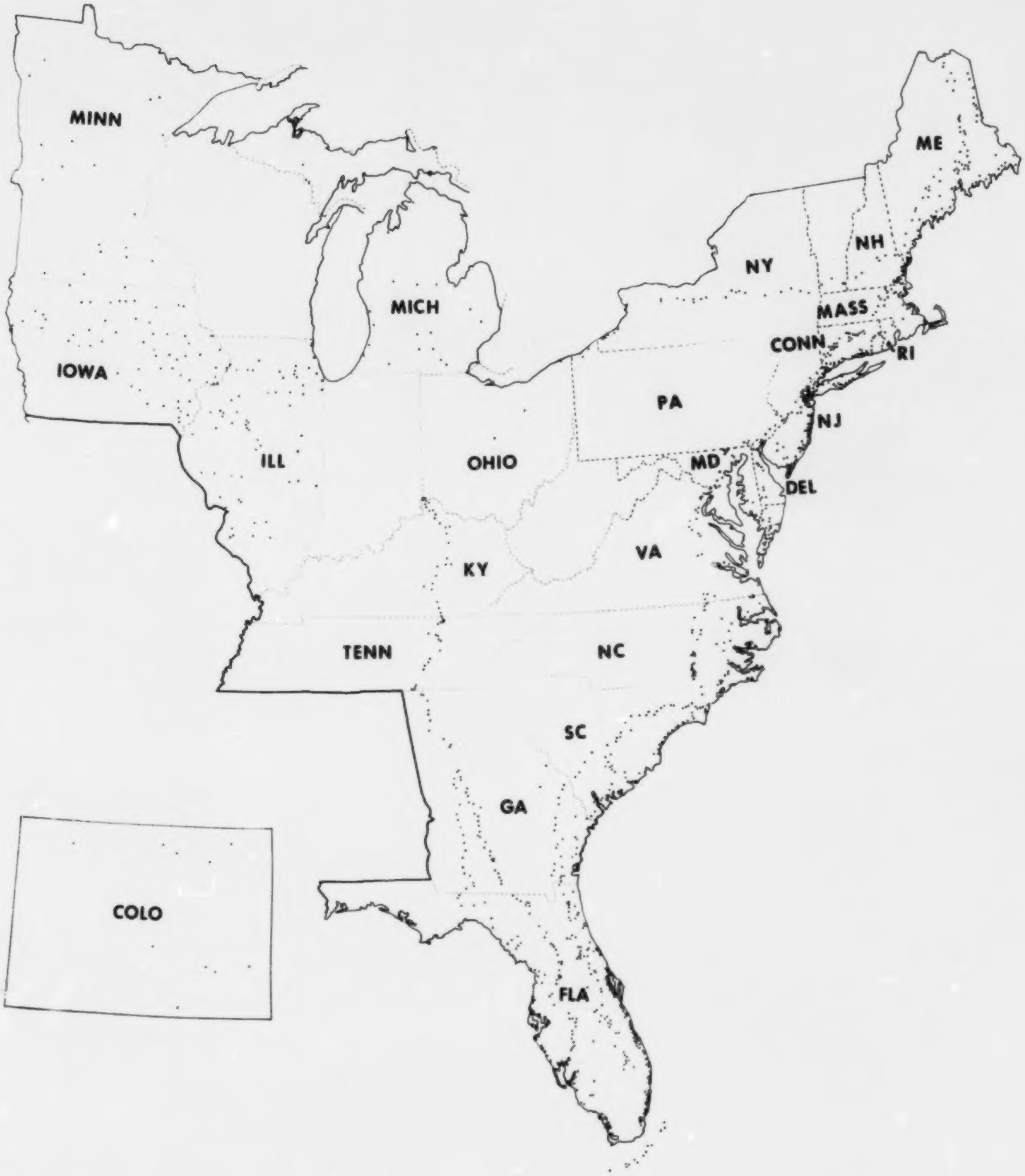
MINN
MICH
IOWA
ILL
OHIO
PA
NY
ME
NH
MASS
CONN
RI
NJ
MD
DEL
VA
KY
TENN
NC
SC
GA
FLA
COLO

Figure 1. Sites where one or more background gamma radiation dose rate measurements were made

137

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters

State and city		Latitude	Longitude	Altitude	Average (µrad/hr)	Number of observations
Colo:	Cannon City	38.26	105.16	5350	13.9	50
	Craig	40.31	107.33	6174	13.5	27
	Ft. Collins	40.35	105.05	4965	13.5	109
	Ft. Morgan	40.15	103.48	4550	14.6	57
	Grand Junction	39.07	108.32	4585	13.9	99
	Greeley	40.25	104.41	4663	13.4	138
	La Junta	38.03	103.31	4100	11.6	51
	Lamar	38.07	102.36	3515	12.1	56
	Rocky Ford	38.02	103.42	4250	12.7	40
	Sterling	40.37	103.12	3939	12.9	68
	Trinidad	37.10	104.29	6200	13.5	65
Conn:	Ashford	41.53	72.08	565	10.0	1
	Berlin	41.40	72.43	350	9.7	3
	Bethel	41.21	73.26	450	10.4	6
	Bolton	41.47	72.27	400	8.7	1
	Bradford	41.15	72.52	40	10.3	4
	Bridgeport	41.10	73.08	7	10.4	5
	Clinton	41.15	72.33	30	8.4	4
	Coscob	41.03	73.35	150	11.4	5
	Coventry	41.48	72.21	480	9.1	1
	Danbury	41.23	73.28	510	9.9	8
	Darien	41.06	73.26	70	10.8	
	Dodgingtown	41.22	73.23	600	10.4	2
	East Hartford	41.47	72.38	120	8.9	6
	East River	41.16	72.38	40	8.6	2
	Eastford	41.54	72.05	540	12.2	3
	Fairfield	41.08	73.15	10	11.1	3
	Guilford	41.16	72.42	30	9.0	3
	Hartford	41.46	72.42	140	9.9	5
	Jewett City	41.38	71.54	400	9.9	3
	Leetes Corner	41.15	72.45	30	12.5	3
	Madison	41.16	72.35	40	9.0	4
	Manchester	41.48	72.29	392	9.1	7
	Mansfield	41.50	72.16	600	9.8	3
	Middlebury	41.33	73.09	800	10.4	2
	Milford	41.12	73.05	30	9.1	5
	Milldale	41.35	72.53	550	9.1	3
	Moosup	41.42	71.52	325	9.3	4
	New Britain	41.41	72.48	200	9.9	3
	New Canaan	41.09	73.30	100	10.8	4
	New Haven	41.17	73.05	25	9.1	12
	New London	41.20	72.05	40	10.4	9
	Newtown	41.23	73.19	700	9.5	4
	Niantic	41.18	72.15	20	11.0	5
	Norwalk	41.07	73.25	37	11.3	6
	Norwich	41.32	72.04	20	10.8	8
	Old Saybrook	41.19	72.18	40	9.3	3
	Pine Orchard	41.15	72.50	30	10.2	2
	Plainfield	41.40	71.53	350	9.1	3
	Plantsville	41.37	72.46	400	8.8	4
	Ridgefield	41.15	73.30	450	10.2	4
	Sound View	41.17	72.17	10	11.4	4
	Southington	41.38	72.45	350	9.4	2
	Southbury	41.28	73.17	900	9.1	4
	Stamford	41.05	73.33	190	11.1	5
	Sterling	41.41	71.49	300	9.8	3
	Stoney Creek	41.16	72.47	30	10.2	1
	Stratford	41.11	73.06	20	10.4	6
	Ucasville	41.28	72.06	20	10.8	3
	Warrenville	41.51	72.10	575	11.8	1
	Waterbury	41.35	73.02	605	10.3	10
	West Hartford	41.45	72.44	150	9.6	7
	Westbrook	41.18	72.26	40	9.6	4
	Westport	41.08	73.25	20	10.9	3
	Wilton	41.12	73.27	300	11.0	3
	Woodbury	41.34	73.16	935	9.5	2
	Woodstock	41.55	72.03	540	11.9	2
Del:	Blackbird	39.20	75.39	35	9.2	1
	Dover	39.09	75.31	25	8.6	7
	Farmington	38.55	75.35	30	8.6	1
	Greenwood	38.50	75.35	40	7.9	2
	Newark	39.40	75.44	90	10.1	4
	Newport	39.45	75.35	80	9.8	3
	Odessa	39.28	75.40	40	9.9	2
	Seaford	38.37	75.37	55	7.9	3
	Symrna	39.15	75.38	35	8.7	3
	Wilmington	39.40	75.36	78	9.8	15
Fla:	Buchanan	27.26	81.50	80	5.9	2
	Bunnel	29.28	81.08	50	6.2	5
	Bushnell	28.40	82.05	75	6.5	4
	Callahan	30.33	81.47	25	9.0	5
	Caloosahatchee River	26.45	81.26	16	7.7	2
	Canal Point	26.52	80.38	25	6.5	3
	Casselberry	28.46	81.14	15	6.1	3
	Charlotte	26.58	82.05	10	6.2	3

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city	Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
Fla: Chiefland	29.27	82.54	40	6.5	3
Citrus	28.29	82.39	18	6.1	2
City Point	28.28	80.49	28	6.0	2
Cleveland	26.59	81.58	10	5.5	2
Coachman	28.04	82.40	8	6.2	1
Cocoa	28.26	80.48	27	6.3	5
Coleman	28.45	82.04	19	6.3	2
Collier	26.30	81.26	10	5.7	5
Connersville	29.16	81.20	40	6.2	2
Copeland	25.58	81.23	4	8.3	2
Crescent Park	29.25	81.30	58	6.9	4
Cross City	29.38	83.08	43	7.2	3
Crystal River	28.50	82.40	15	5.9	5
Dade City	28.20	82.06	18	7.7	3
Dania	26.04	80.12	7	6.0	5
De Bary	28.53	81.17	40	6.1	4
De Leon Springs	29.12	81.18	40	6.8	4
De Sota	27.03	81.55	15	5.9	1
Deerfield Beach	26.20	80.05	20	5.9	3
Deland	29.04	81.17	40	6.3	8
Delray Beach	26.28	80.05	15	6.1	4
Denver	29.22	81.27	50	6.6	1
Dinsmore	30.28	81.45	24	7.4	2
Dupont Center	29.29	81.09	50	6.5	4
Durbin	30.04	81.25	15	6.4	2
East Palatka	29.39	81.37	20	6.5	3
East of Facil	30.19	82.46	175	5.1	3
East Tampa	27.58	82.32	25	8.0	4
Eau Gallie	28.06	80.37	15	5.9	6
Econfina River	30.23	83.40	100	7.2	4
Edgewater	28.58	80.54	30	7.4	4
Eldred	27.27	80.15	30	6.2	3
Eldridge	29.14	81.19	40	7.2	2
Estero	26.28	81.51	15	6.7	2
Favorita	29.20	81.06	40	5.9	2
Facil	30.19	82.47	160	8.3	1
Florida City	25.25	80.30	11	6.6	3
Ft. Drum	27.35	80.51	60	6.0	2
Ft. Lauderdale	26.06	80.10	16	6.6	30
Ft. Meade	27.43	81.49	122	9.2	5
Ft. Myers	26.35	81.52	15	7.5	4
Ft. Ogden	27.05	81.54	25	6.1	2
Ft. Pierce	27.28	80.21	30	6.2	7
Frontenac	28.34	80.50	30	5.9	2
Gainsville	29.38	82.22	86	7.4	6
Garden Cove	25.13	80.29	14	6.1	3
Gardner	27.24	81.51	70	6.2	2
Genoa	30.25	82.51	160	6.9	2
Gibsonton	27.55	82.30	25	6.7	2
Goulds	25.35	80.24	11	7.8	4
Greater Miami	25.43	80.17	15	6.5	14
Green Cove	30.00	81.45	17	6.9	5
Hague	29.47	82.29	85	6.5	1
Hardeetown	29.28	82.55	42	6.3	4
Hernando	28.25	82.40	20	5.7	1
Hibernia	30.03	81.43	17	7.1	2
High Spring	29.50	82.36	75	7.5	7
Highland Cove	27.57	81.53	175	9.7	5
Hilliard	30.40	81.48	25	7.6	3
Hobe Sound	27.04	80.10	10	6.7	2
Hollandale	25.59	80.16	15	6.3	3
Hollywood	26.03	80.13	10	5.9	5
Holopaw	28.09	81.10	50	5.7	3
Homeland	27.45	81.50	125	9.8	1
Homestead	25.30	80.30	11	7.2	4
Homosassa	28.38	82.39	18	5.9	2
Hopewell	28.01	82.10	100	8.2	3
Hudson	28.20	82.42	10	6.1	2
Iamonia	31.34	84.19	48	8.5	3
Immokolee	26.28	81.26	10	6.3	5
Indian River	28.36	80.50	30	7.3	1
Indrio	27.31	80.23	30	6.5	3
Inglis	29.02	82.41	12	6.2	3
Islamorada	24.52	80.39	4	5.8	2
Jacksonville	30.25	81.39	24	7.9	28
Jasper	30.29	82.55	140	6.8	2
Junction route 415 and 192	28.08	81.08	50	5.8	1
Jensen Beach	27.15	80.14	15	5.9	4
Jerome	26.00	81.22	4	7.5	2
Juno Beach	26.48	80.08	10	6.3	3
Jupiter	26.55	80.09	10	6.0	2
Keanansville	27.50	81.00	60	5.8	3
Key Colony	25.00	80.40	11	5.8	2
Key Largo	25.09	80.28	10	6.4	3

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (µrad/hr)	Number of observations
Fla:	Key West	24.33	81.48	6	6.2	13
	Kirkwood	29.26	82.11	70	6.8	1
	Kissimmee	28.17	81.25	60	5.9	3
	Kronoa	29.24	81.07	40	5.9	3
	Lake City	30.11	82.36	205	7.3	6
	La Grange	28.38	80.51	35	6.8	2
	Lake Polk	27.55	81.45	100	6.0	1
	Lake Worth	26.39	80.06	15	6.0	4
	Lakeland	28.02	81.57	214	8.2	8
	Lamont	30.24	83.55	213	7.8	6
	Lantana	26.38	80.05	15	5.7	3
	Laurel	27.12	82.27	15	7.4	1
	Lebanon Station	29.15	82.39	12	6.7	4
	Lee & Charlotte County	26.45	81.45	10	5.8	3
	Lokosee	27.43	80.57	60	5.8	2
	Long Beach	24.25	81.20	10	6.9	2
	Long Key	24.45	80.49	4	5.6	4
	Lowell	29.15	82.08	80	12.1	3
	Malabar	28.00	80.34	15	6.1	2
	Marathon	24.40	81.10	11	5.9	4
	Margate	26.25	80.08	18	6.1	6
	Martin	29.13	82.08	80	9.8	1
	Matecumbe Beach	24.48	80.44	4	5.6	1
	McIntosh	29.25	82.10	75	8.1	3
	Mecca	28.06	82.42	8	6.2	3
	Melbourne	28.04	80.36	10	6.0	4
	Miami	25.43	80.17	15	6.8	11
	Micanopy	29.26	82.11	75	6.5	1
	Micco	27.50	80.32	20	6.0	2
	Miles City	26.11	81.22	10	6.8	1
	Mims	28.40	80.51	35	6.6	3
	Modello	25.32	80.29	10	8.1	4
	Moultrie	29.45	81.20	15	6.5	2
	Naples	26.13	81.51	15	5.9	5
	Naranja	25.33	80.28	10	7.5	3
	National	29.17	81.05	40	6.1	3
	New Smyrna	29.01	80.55	30	6.9	4
	Nittaw	27.56	81.00	60	5.7	2
	Nocatee	27.08	81.53	40	6.5	2
	Nokomis	27.10	82.27	10	7.0	2
	N. Palm Beach	26.45	80.08	10	6.0	4
	N. Port Charles	27.02	82.08	30	6.8	3
	Nursery Grove	27.52	80.33	20	6.0	2
	Oak Hill	28.50	80.53	30	6.1	3
	Ocala	29.11	82.08	86	10.0	5
	Ochopee	25.55	81.15	15	6.2	6
	Ojus	25.58	80.16	15	6.0	4
	Okeechobee	27.13	80.48	34	5.9	5
	Orange City	28.57	81.18	40	6.5	4
	Orange Lake	29.23	82.09	80	8.3	2
	Orange Park	30.05	81.40	18	8.0	5
	Orlando	28.33	81.20	108	6.5	8
	Ormond Beach	29.09	81.03	30	7.4	5
	Oslo	27.32	80.24	30	6.2	3
	Osowaw Junction	27.30	80.52	60	6.0	2
	Osprey	27.17	82.27	15	6.3	2
	Otter Creek	29.20	82.40	10	6.2	3
	Oxford	28.55	82.03	18	7.8	1
	Pahokee	26.46	80.38	10	6.5	4
	Palatka	29.39	81.38	15	6.7	5
	Palm Bay	28.02	80.35	10	6.4	3
	Palm Shore	28.13	80.41	15	5.8	2
	Palmeto	27.30	82.28	15	6.9	4
	Pembroke	27.44	81.50	125	10.6	1
	Perrine	25.36	80.21	11	7.2	3
	Perry	30.07	83.36	45	6.9	5
	Pierson	29.15	81.20	40	6.3	3
	Pineda	28.20	80.45	15	6.0	2
	Piney Point	27.32	82.28	15	5.5	1
	Pinto Drive	29.11	81.03	31	6.7	13
	Point Laurel	25.27	80.20	14	5.9	3
	Pomona Park	29.33	81.37	45	6.7	3
	Pompano Beach	26.14	80.09	22	6.4	6
	Port Charlotte	27.02	82.08	10	6.7	7
	Port Mayac	26.59	80.37	38	6.1	3
	Port Richey	28.15	82.45	8	7.7	3
	Port Salerno	27.11	80.17	10	5.9	4
	Poxsee	27.45	80.59	60	5.8	2
	Princeton	25.34	80.26	11	7.7	3
	Punta Gorda	26.58	81.58	9	6.6	5
	Ramrod Key	24.25	81.20	10	6.4	2
	Reddick	29.22	82.09	80	9.1	1
	Relief Channel	24.49	80.42	4	5.4	2
	Rio	27.14	80.14	10	5.5	1
	Riviera Beach	26.43	80.07	14	6.1	5

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (µrad/hr)	Number of observations
Fla:	Rock Harbor	25.06	80.29	5	5.9	2
	Rockledge	28.25	80.48	20	6.0	2
	Royal Palm	26.39	80.06	20	6.2	8
	Ruskin	27.35	82.30	15	6.1	4
	Salem	29.45	83.30	45	6.2	3
	San Carlos	26.30	81.52	15	7.4	2
	San Mateo	29.35	81.37	30	6.8	2
	Sand Cut	26.55	80.38	30	6.2	3
	Sanford	28.48	81.15	14	6.6	7
	Santos	29.09	82.06	86	8.0	1
	Sarasota	27.21	82.32	30	7.6	7
	Satsuma	29.34	81.38	30	6.5	3
	Scotts Moor	28.45	80.52	30	6.8	3
	Sebastian	27.45	80.31	20	6.0	3
	Seville	29.17	81.25	40	6.6	3
	Shamrock	29.39	83.09	43	5.9	3
	Sharpes	28.29	80.49	30	6.1	3
	South Venice	27.03	82.20	30	6.0	1
	St. Augustine	29.53	81.20	15	7.2	9
	St. Cloud	28.13	81.23	50	5.8	4
	St. Johns	30.11	81.29	15	6.4	1
	St. Lucie	27.30	80.22	30	6.8	3
	St. Petersburg	27.46	82.38	8	7.0	21
	Stuart	27.13	80.15	10	6.0	4
	Summerfield	29.01	82.03	15	8.3	1
	Summerland	24.25	81.25	8	6.1	3
	Sumpterville	28.42	82.04	19	6.4	1
	Sun City	27.34	82.29	15	5.0	1
	Sunbeam	30.15	81.35	15	6.7	3
	Sunniland	26.20	81.25	10	6.8	2
	Tallahassee	30.23	84.22	55	8.9	7
	Tampa	27.58	82.32	19	8.0	11
	Tarpon Springs	28.09	82.45	8	6.9	3
	Tavernier	25.01	80.31	5	6.0	6
	Titusville	28.37	80.50	40	5.9	5
	Tomoka Estates	29.13	81.04	40	6.4	3
	Trilacodches	28.30	82.05	18	9.4	1
	Turnbull	28.43	80.52	32	6.7	1
	Up The Grove	27.05	80.42	40	5.4	2
	Valhalla	24.55	80.45	11	6.2	2
	Valkaria	27.56	80.34	15	6.0	2
	Valroy	27.33	82.28	15	5.3	1
	Venice	27.06	82.27	10	6.6	1
	Vero Beach	27.38	80.27	20	8.0	6
	Wabasso	27.43	80.30	20	6.0	3
	Walton	27.20	80.14	15	6.1	5
	Wauchula	27.35	81.49	119	6.8	6
	Waukeenah	30.23	83.58	150	8.3	4
	Weekiwachee	28.27	82.40	18	6.6	2
	Wesconnet	30.13	81.39	20	7.9	3
	West Palm Beach	26.41	80.06	15	6.1	13
	White City	27.26	80.20	30	5.9	3
	White Springs	30.17	82.45	190	6.5	3
	Wildwood	28.50	82.03	19	6.9	3
	Williams Port	28.32	80.50	30	6.4	1
	Winfield	30.15	82.45	195	7.1	2
	Winter Beach	27.41	80.28	20	7.1	3
	Yeehaw Junction	27.40	80.55	60	5.8	3
	Yukon	30.10	81.39	20	7.5	3
	Yulee	30.29	81.33	25	8.3	3
	Zelfo Springs	27.30	81.50	90	6.8	3
	Zephyrhill	28.13	82.05	18	6.7	3
Ga:	Adairsville	34.21	84.56	720	10.4	3
	Adel	31.07	83.25	240	7.9	4
	Albany	31.32	84.08	180	8.4	8
	Americus	32.06	84.10	476	8.6	6
	Arabi	31.43	83.39	400	8.3	3
	Ashburn	31.40	83.37	435	8.5	5
	Atlanta	33.39	84.26	1010	10.6	9
	Barnsville	33.07	84.09	600	14.5	4
	Beachton	30.50	83.59	200	8.8	2
	Broadhurst	31.27	81.53	100	8.2	2
	Brunswick	31.09	81.30	10	8.5	17
	Butler	32.33	84.14	625	9.1	5
	Calhoun	34.29	84.58	650	9.4	2
	Camilla	31.14	84.13	175	8.4	5
	Cartersville	34.09	84.50	685	10.5	7
	Cecil	31.03	83.24	245	8.0	1
	Chula	31.32	83.33	375	8.1	1
	Claxton	32.09	81.53	180	8.0	3
	Colesburg	30.55	81.40	20	8.9	2
	Cordele	31.58	83.47	305	8.2	6
	Culloden	32.53	84.04	500	13.4	3

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city	Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
Ga: Dalton	34.46	84.57	720	9.1	6
Darien	31.20	81.27	15	11.4	7
Donegal	32.15	81.48	175	8.0	1
Dougherty	31.28	84.11	150	8.9	3
Echota	34.32	84.58	650	10.8	1
Ellaville	32.10	84.13	500	8.6	3
Eulonia	31.30	81.30	15	9.1	3
Fender	31.15	83.30	300	8.3	1
Folkstone	30.48	82.02	30	7.5	6
Florida and Georgia Line	30.50	83.19	270	6.9	3
Ft. Valley	32.34	83.51	490	9.0	3
Freedman	31.46	81.30	60	8.8	1
Garden City	32.04	81.13	40	9.3	3
Glennville	31.56	81.55	175	8.0	7
Glynco	31.45	81.20	15	10.3	1
Griffin	33.15	84.16	980	12.4	5
Hahira	30.58	83.23	250	8.6	3
Henderson	32.27	83.45	425	9.0	1
Hickox	31.08	81.59	50	8.8	2
Hortense	31.10	81.53	100	8.6	3
Inaha	31.34	83.34	0	9.0	1
Junction route 301 and 24	32.54	81.04	200	8.5	2
Jesup	31.37	81.53	100	7.7	6
Kingsland	30.45	81.40	30	9.2	3
Lee Pope	32.38	83.53	400	9.0	1
Leesburg	31.40	84.08	200	8.8	2
Lenox	31.12	83.26	230	8.0	2
Ludowici	31.40	81.51	150	7.9	3
Marietta	33.58	84.28	800	9.6	4
Meigs	31.04	84.05	190	8.0	2
Midway	31.45	81.30	60	8.1	3
Milner	33.12	84.11	575	14.2	3
Musella	32.47	83.58	455	9.5	1
Nahunta	31.11	81.58	71	8.6	3
Ochlocknee	30.58	84.03	200	9.0	2
Orchard Hill	33.14	84.13	565	9.2	1
Pelham	31.07	84.08	180	8.7	3
Perry	32.35	83.45	450	8.9	4
Pike and Spaulding Counties	33.15	84.20	750	10.5	1
Pike and Upton Counties	33.00	84.19	700	10.1	1
Pinehurst	32.20	83.46	350	7.6	2
Resaca	34.34	84.57	650	9.9	1
Riceboro	31.42	81.30	15	8.7	4
Richmond Hill	31.47	81.30	80	9.3	4
Ringgold	34.55	85.07	820	9.5	2
Roberta	32.43	83.55	435	12.7	6
Schley and Taylor County	32.13	84.13	575	8.9	3
South Atlanta	33.31	84.21	930	11.7	1
South Savannah	31.58	81.17	25	8.7	1
Savannah	32.08	81.12	22	9.5	14
Statesboro	32.13	81.50	150	8.4	8
Sparks	31.09	83.25	235	7.9	2
Smithville	31.55	84.10	300	9.2	2
Stone Mt. Park	33.45	84.15	1500	11.8	2
Sycamore	31.38	83.35	400	8.2	3
Sylvania	32.45	81.39	254	8.5	6
Thomaston	32.52	84.19	665	10.5	7
Thomasville	30.52	84.00	230	8.6	5
Tifton	31.28	83.31	360	8.3	6
Tillman	30.55	83.22	250	8.4	1
Unadilla	32.22	83.45	400	8.3	3
Valdosta	30.52	83.20	265	8.0	5
Vienna	32.10	83.47	325	7.8	3
Waverly	31.07	81.51	70	9.1	3
Wenona	31.45	83.40	350	7.8	2
Wentworth	32.07	81.13	46	8.3	3
White Oak	31.03	81.40	20	9.0	2
Winokur	31.01	81.60	40	8.9	2
Woodbine	30.58	81.40	20	8.6	4
Zebulon	33.13	84.19	725	11.6	3
Ill: Abington	40.45	90.30	650	9.3	7
Armington	40.14	89.24	500	9.2	4
Atlanta	40.12	89.19	500	9.3	5
Auburn	39.32	89.55	600	9.7	6
Aurora	41.45	88.20	744	8.1	16
Batavia	41.45	88.15	700	7.9	6
Belleville	38.30	89.51	450	9.8	9
Benld	39.10	89.50	600	9.9	6
Brimfield	40.48	89.55	600	9.7	5
Bushnell	40.32	90.33	600	9.4	9
Carlyle	38.38	89.20	501	9.6	6
Carthage	40.25	91.15	500	9.1	6
Charleston	39.29	88.11	710	8.8	8
Crete	41.27	87.38	660	9.3	6
Creve Coeur	40.38	89.40	600	9.2	6

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (μrad/hr)	Number of observations
Ill:	De Kalb	41.50	88.40	800	8.1	13
	Dixon	41.50	89.29	696	7.6	12
	Dwight	41.07	88.30	475	9.7	6
	Elgin	42.02	88.17	820	8.5	14
	Elmhurst	41.50	87.55	500	8.5	14
	Elmwood	40.45	90.10	600	9.6	1
	Farmington	40.40	90.00	630	9.7	7
	Freeburg	38.27	86.56	550	9.8	6
	Fulton	41.54	90.09	592	8.2	6
	Galesburg	40.57	90.24	771	9.4	3
	Galva	41.10	90.02	855	9.1	6
	Geneva	41.43	88.13	700	7.8	6
	Glencoe	42.05	87.45	600	8.5	7
	Jerseyville	39.06	90.21	630	9.6	6
	Joliet	41.32	88.05	520	8.1	15
	Kewanee	41.15	89.55	820	9.0	10
	Knoxville	40.55	90.32	700	9.7	6
	Lake Bluff	42.30	87.50	600	8.6	6
	Lincoln	40.09	89.22	591	9.0	6
	Lemont	41.40	87.55	500	9.0	6
	Lansing	41.35	87.30	500	8.6	9
	Lockport	41.34	88.05	585	8.5	6
	Marshall	39.23	87.41	570	8.2	6
	Mattoon	39.28	88.21	718	9.1	9
	Milstadt	38.20	90.08	400	9.9	6
	Monmouth	40.55	90.38	770	9.1	8
	Morris	41.21	88.26	520	8.7	6
	Morrison	41.49	89.58	603	8.3	6
	Mount Vernon	38.19	88.55	500	9.5	7
	Nashville	38.23	89.20	515	9.7	6
	New Athens	38.15	86.50	600	9.8	6
	Odin	38.38	89.04	500	9.1	6
	Oglesby	41.15	89.04	500	8.2	6
	Oregon	42.00	89.20	690	8.2	6
	Ottawa	41.22	88.50	474	8.7	6
	Paxton	40.30	88.15	475	8.8	6
	Peoria Heights	40.42	89.41	600	9.0	6
	Pittsfield	39.37	90.45	640	9.3	8
	Rock Island	41.30	90.30	500	8.3	15
	Roxanna	38.49	90.09	500	8.6	6
	Sandwich	41.39	88.35	700	8.3	6
	Silvis	41.30	90.15	700	8.5	6
	South Pekin	40.30	89.55	600	8.1	6
	Staunton	39.03	89.50	550	9.9	6
	Sterling	41.45	89.34	600	8.4	12
	Tremont	40.31	89.50	600	9.3	6
	Urbana	40.06	88.14	743	9.4	11
	Waukegan	42.22	87.52	680	8.7	16
	Waverly	39.32	90.05	600	9.7	5
	Wilmington	41.15	88.05	600	8.4	6
	Winchester	39.32	90.30	500	9.0	6
	Wood River	38.50	90.08	480	8.5	7
Iowa:	Alden	42.31	93.19	1100	8.0	6
	Algona	43.04	94.18	1230	8.6	7
	Atkins	42.00	91.50	750	8.8	6
	Aurelia	42.40	95.30	1100	9.3	6
	Belle Plaines	41.54	92.16	855	8.5	6
	Bellevue	42.16	90.25	603	8.1	6
	Blue Grass	41.30	90.38	500	8.9	6
	Boxholm	42.10	94.10	900	9.0	6
	Bristow	42.45	92.52	1000	8.5	6
	Cedar Rapids	41.53	91.42	840	8.5	21
	Cherokee	42.47	95.33	1250	9.4	8
	Churdan	42.08	94.15	950	9.3	6
	Clarion	42.43	93.45	1165	8.2	6
	Clear Lake	43.10	93.22	1100	8.6	6
	Clinton	41.50	90.13	595	8.6	14
	Colfax	41.30	93.08	925	9.5	6
	Danville	40.52	91.20	700	8.9	6
	De Witt	41.49	90.34	685	8.7	7
	Donnellson	40.42	91.24	715	8.4	7
	Dubuque	42.24	90.42	1056	8.5	17
	Dysart	42.12	92.15	900	8.6	6
	Estherville	43.24	94.50	1298	8.7	7
	Eldridge	41.38	90.35	500	8.7	6
	Fairfield	41.02	91.57	754	8.8	8
	Ft. Dodge	42.31	94.10	1111	8.5	12
	Garner	43.08	93.38	1150	8.8	7
	Grinnell	41.43	92.44	910	8.8	7
	Holstein	42.29	95.32	1370	9.8	7
	Hopkinton	42.20	91.08	800	7.8	6
	Iowa City	41.39	91.32	640	8.9	12
	Jesup	42.30	91.58	900	8.0	6
	Kingsley	42.35	95.55	1000	10.2	6

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (µrad/hr)	Number of observations
Iowa:	Lake City	42.16	94.44	1235	9.0	7
	Manchester	42.30	91.25	900	8.3	7
	Marcus	42.45	95.50	1000	10.2	6
	Marengo	41.45	92.06	800	8.6	6
	Mason City	43.09	93.20	1194	8.5	12
	Morning Sun	41.08	91.08	500	9.3	6
	Mt. Pleasant	40.58	91.33	720	9.2	10
	New Hampton	43.03	92.18	1155	8.1	7
	New London	40.56	91.30	700	9.1	7
	Nora Spring	43.11	93.00	1100	8.6	6
	Northwood	43.27	93.13	1210	8.4	7
	Oskaloosa	41.17	92.41	770	9.7	8
	Ossian	43.12	91.45	1100	9.2	6
	Ottumwa	41.06	92.27	842	9.0	12
	Oxford	41.44	91.37	600	8.9	6
	Pella	41.25	92.55	870	9.3	6
	Pottsville	43.10	91.32	1100	8.8	6
	Reinbeck	42.15	92.35	900	8.7	6
	Rockwell City	42.24	94.37	1210	8.9	6
	Sergeant Bluffs	42.25	96.28	900	10.2	5
	Sioux City	42.24	96.23	1095	9.7	20
	Springville	42.08	91.25	800	8.2	8
	Stacyville	43.27	92.45	1100	8.7	6
	Stanhope	42.15	93.45	1000	8.8	6
	Waterloo	42.33	92.24	868	8.3	20
	Waverly	43.18	92.28	1000	9.1	8
	West Bend	42.55	94.30	1000	8.8	6
	West Liberty	41.32	91.10	600	9.0	7
	West Point	40.35	91.29	700	8.6	6
	Winfield	41.10	91.28	550	9.0	6
	Wyoming	42.07	91.00	800	8.6	6
Ky:	Bracht	38.52	84.40	860	9.8	1
	Burnside	36.58	84.34	1100	8.9	2
	Camp Dick	37.45	84.35	1100	10.9	3
	Camp Nelson	37.45	84.35	1100	11.3	1
	Camp Robinson	37.44	84.36	1100	10.8	2
	Corinth	38.20	84.34	890	10.2	2
	Crittenden	38.49	84.39	870	9.3	2
	Dry Ridge	38.46	84.38	900	8.8	1
	Edgewood	39.03	84.44	800	9.7	1
	Erlanger	39.01	84.45	800	9.3	2
	Eubank	37.23	84.35	1200	9.7	3
	Lancaster	37.37	84.35	1032	9.4	2
	Lake Side	39.04	84.44	800	9.4	1
	Georgetown	38.12	84.33	888	9.4	4
	Florence	39.00	84.46	800	9.5	3
	Lexington	38.02	84.36	966	9.7	6
	Mason	38.37	84.35	900	9.8	1
	Nicholasville	37.50	84.33	1000	9.1	2
	Pine Knot	36.40	84.29	1300	8.0	2
	Richwood	38.58	84.45	825	9.3	2
	Sherman	38.47	84.39	880	10.1	1
	Sloans Valley	36.50	84.32	1250	9.4	1
	Somerset	37.06	84.37	955	9.1	3
	South Mitchell	39.05	84.43	800	9.8	1
	Stanford	37.25	84.40	955	9.3	2
	Stearns	36.43	84.29	1420	8.0	2
	Strunk	36.38	84.28	1300	7.6	1
	Walton	38.56	84.43	850	9.9	2
	Whitley City	36.45	84.30	1300	9.4	3
	Williamston	38.39	84.37	920	9.8	3
Maine:	Ashland	46.33	68.28	100	8.8	2
	Auburn	44.06	70.16	180	10.4	3
	Augusta	44.19	69.47	250	9.9	8
	Bangor	[illegible]	68.49	202	9.6	9
	Beddington	44.52	68.03	1000	9.6	1
	Belfast	44.24	69.00	20	9.3	5
	Biddeford	43.30	70.27	80	11.1	5
	Bridgewater	46.24	67.51	450	9.0	3
	Brunswick	43.54	69.56	70	10.6	3
	Bucksport	44.33	68.40	20	9.8	4
	Burnham	44.39	69.31	95	9.3	3
	Calais	45.10	67.12	130	9.9	7
	Camden	44.14	69.05	50	9.8	5
	Caribou	46.52	68.01	624	9.6	5
	Carmel	44.48	69.04	175	9.4	3
	Clifton	44.52	68.09	500	9.2	2
	Clinton	44.38	69.30	95	9.6	4
	Columbia Falls	44.38	67.48	35	10.3	2
	Costigen	45.01	68.40	100	9.0	3
	Dedham	44.52	68.10	500	9.7	2
	Eagle Lake	47.05	68.36	300	9.4	2
	Ellsworth	44.32	68.26	24	10.2	5
	Etna	44.48	69.06	150	9.4	2

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (µrad/hr)	Number of observations
Maine:	Fort Kent	47.15	68.36	530	9.0	5
	Freeport	43.50	70.04	40	10.9	3
	Gorham	43.40	70.30	50	11.3	3
	Gouldboro	44.30	68.05	30	9.9	2
	Grawford	45.05	67.32	100	9.7	2
	Gray	44.07	70.17	150	12.7	9
	Greenfield	45.04	68.37	150	9.1	3
	Grindstone	45.45	68.35	500	9.1	2
	Hancock	44.32	68.15	20	10.2	3
	Haynesville	45.50	67.59	380	9.4	3
	Hermon	44.48	69.00	190	9.6	3
	Houlton	46.08	67.50	410	9.1	3
	Kennebunk	43.25	70.30	100	10.9	3
	Kittery	43.00	70.45	40	9.4	6
	Lewiston	44.06	70.14	182	11.1	3
	Lincoln	45.25	68.30	212	9.9	3
	Linneus	46.04	67.58	390	10.2	2
	Littleton	46.20	67.50	425	9.0	2
	Machias	44.43	67.28	40	10.0	5
	Machias River	44.54	67.54	130	9.6	1
	Macwahoc	45.35	68.09	350	9.4	1
	Mars Hill	46.32	67.51	500	8.9	3
	Masardis	46.30	68.27	100	8.9	7
	Matawamkea	45.30	68.20	200	9.6	3
	Medway	45.35	68.31	600	9.4	1
	Milbridge	44.32	67.56	30	9.9	4
	Milford	44.58	68.40	100	9.0	2
	Milford City	44.58	68.40	100	9.2	1
	Monticello	46.28	67.50	440	8.9	3
	Newport	44.46	69.25	100	9.5	3
	Nobleboro	44.10	69.20	80	10.1	2
	Northport	44.19	68.58	30	8.8	2
	Ogunquit	42.15	70.32	45	10.0	1
	Orono	44.52	68.42	115	9.2	3
	Palermo	44.23	69.30	200	9.1	4
	Passadum	45.07	68.40	150	9.1	3
	Patten	45.59	68.27	800	9.5	3
	Perry	44.55	67.08	50	10.8	3
	Pittsfield	44.42	69.30	100	9.7	2
	Plaisted	47.08	68.36	400	9.5	2
	Portage	46.40	68.30	100	8.8	3
	Portland	43.39	70.19	47	10.9	10
	Presque Isle	46.39	68.00	606	9.0	5
	Saco	43.30	70.27	80	11.2	6
	Sanford	43.23	70.50	100	11.7	4
	Scarboro	43.35	70.22	100	11.2	9
	Searsmount	44.25	69.08	150	9.2	2
	Sherman Station	45.50	68.27	600	9.1	3
	South Bath	43.54	69.54	70	10.3	3
	South Kittery	43.05	70.45	40	9.7	3
	South Lincoln	45.18	68.35	175	9.6	3
	Thomaston	44.10	69.10	70	9.2	4
	Waterville	44.33	69.39	89	9.5	5
	Waterboro	43.30	70.48	75	10.7	3
	Wells	43.20	70.31	60	10.2	4
	Wesley	44.56	67.38	50	10.0	3
	West Aurora	44.52	68.09	500	9.6	3
	Whiting	44.45	67.15	30	9.4	5
	Winslow	44.31	69.39	89	9.5	3
	Winterville	47.02	68.37	500	8.6	3
	Winthrop	44.19	69.55	200	9.6	4
	Wiscassett	44.00	69.18	100	9.7	3
	York	43.10	70.42	40	10.1	2
	York Harbor	43.10	70.42	40	10.3	1
Md:	Baltimore	39.17	76.37	14	8.0	17
	Bel Air	39.30	76.27	20	8.4	5
	Brentwood	38.57	76.58	70	7.2	1
	Calvert	39.43	76.07	60	9.1	2
	Cambridge	38.34	76.09	20	8.3	8
	College Park	38.59	76.56	70	8.4	4
	Conowingo	39.39	76.10	40	8.6	2
	Delmar	38.26	75.35	20	9.2	1
	Eden	38.16	75.39	12	7.7	1
	Elkridge	39.12	76.42	20	9.3	4
	Fairhill	39.45	76.06	70	9.5	3
	Fruitland	38.18	75.37	10	8.1	1
	Hyattsville	38.57	76.58	70	8.[illegible]	2
	Kingsville	39.26	76.32	18	8.[illegible]	3
	Laurel	39.06	76.54	400	8.[illegible]	4
	Pocomoke City	38.03	75.34	20	7.8	2
	Princess Anne	38.12	75.41	15	7.8	2
	Rising Sun	39.41	76.08	50	8.6	3
	Salisbury	38.22	75.35	10	7.7	8
	Savage	39.08	76.52	40	8.9	3

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (µrad/hr)	Number of observations
Md:	Vienna	38.30	76.07	20	7.9	3
	Westover	38.08	75.42	17	8.6	2
Mass:	Acton	42.28	71.28	100	11.1	3
	Auburn	42.08	71.54	800	11.6	8
	Barnstable	41.38	70.15	20	9.4	6
	Beverly	42.34	70.52	40	10.3	5
	Boston proper	42.22	71.02	15	9.8	36
	Brewster	41.45	70.08	40	9.6	4
	Chelmsford	42.33	71.20	90	10.2	6
	Cohasset	42.14	70.48	20	9.2	1
	Dennis	41.42	70.09	20	10.4	7
	Duxbury	42.03	70.45	40	8.5	6
	East Sandwich	41.46	70.30	20	9.8	2
	Essex	42.45	70.47	60	9.7	2
	Gleasondale	42.25	71.32	400	10.6	3
	Gloucester	42.37	70.40	60	11.4	7
	Harwich	41.39	70.07	30	8.0	6
	Haverhill	42.46	71.06	60	10.8	8
	Hudson	42.23	71.32	400	10.3	3
	Hyannis	41.41	70.16	35	9.7	5
	Lawrence	42.42	71.10	57	10.4	9
	Lexington	42.39	71.00	90	9.6	8
	Littleton	42.31	71.21	100	11.0	3
	Lowell	42.39	71.19	90	10.4	5
	Lynn	42.28	70.35	20	10.1	4
	Magnolia	42.35	70.45	60	11.0	4
	Manchester	42.35	70.46	60	10.5	4
	Manomet	41.50	70.35	30	9.3	13
	Marlboro	42.20	71.30	500	10.7	4
	Marshfield	42.05	70.33	40	8.8	8
	Maynard	42.25	71.29	100	10.3	4
	Merrimac	42.55	71.02	40	10.2	3
	Methuen	42.44	71.13	55	9.5	1
	Newburyport	42.50	70.55	20	10.5	5
	North Carver	41.55	70.45	25	8.8	6
	North Scituate	42.13	70.45	20	8.7	1
	Northboro	42.18	71.38	700	10.2	4
	Orleans	41.47	70.00	40	8.3	7
	Plymouth	41.59	70.42	25	9.8	11
	Quincy	42.15	71.00	15	9.7	9
	Rowley	42.45	70.55	50	9.7	8
	Sagamore	41.45	70.35	20	9.4	3
	Salem	42.32	70.52	26	10.1	5
	Sandwich	41.46	70.30	20	9.3	4
	Saugus	42.25	70.58	20	10.0	2
	Scituate	42.12	70.45	20	8.9	1
	South Essex	42.37	70.47	60	10.3	3
	South Yarmouth	41.39	70.16	35	8.0	2
	Southbridge	42.03	72.05	720	12.3	6
	Taunton	41.54	71.04	20	9.7	9
	Wakefield	42.30	71.04	30	10.0	6
	Waterville	41.54	71.00	20	9.3	2
	West Yarmouth	41.41	70.14	35	9.1	4
	Weymouth	42.13	70.58	15	9.7	3
	Winchester	42.00	71.09	90	9.8	9
	Wingham	42.14	70.55	30	9.6	6
	Woburn	42.20	71.10	90	9.7	1
	Worchester	42.16	71.52	986	11.1	9
	Yarmouth	41.38	70.15	20	9.2	5
	Ypswich	42.40	70.52	80	9.6	7
Mich:	Adrian	41.55	84.01	800	9.2	126
	Albion	42.15	84.46	940	8.0	82
	Alpena	45.04	83.34	903	7.2	107
	Benton Harbor	42.08	86.26	642	7.2	104
	Big Rapids	43.42	85.29	928	7.4	66
	Charlotte	42.33	84.50	880	7.7	58
	Grand Haven	43.04	86.13	603	7.1	83
	Holland	42.42	86.06	680	7.3	145
	Iron Mountain	45.50	88.04	1164	8.2	107
	Ishpeming	46.29	87.39	1419	8.5	80
	Jackson	42.17	84.24	1000	7.9	227
	Kingsford	45.50	88.04	1164	8.5	52
	Lapier	43.02	83.20	844	8.4	77
	Marquette	46.34	87.24	1419	8.4	100
	Mason	42.34	84.30	880	7.7	51
	Midland	43.37	84.15	628	7.4	244
	Mt. Pleasant	43.35	84.46	755	7.2	88
	Petoskey	45.23	84.58	700	6.6	63
	Romeo	42.49	83.01	730	8.3	51
	Saulte St. Marie	46.28	84.22	580	8.2	111
	South Haven	42.24	86.17	663	7.3	73
	Tecumseh	41.58	83.58	815	8.7	72
	Three Rivers	41.56	85.38	830	8.0	88
	Traverse City	44.45	85.37	623	6.8	99

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (µrad/hr)	Number of observations
Minn:	Alexandria	45.52	95.23	1425	8.5	64
	Cloquet	46.42	92.31	1278	9.1	87
	Crookston	47.48	96.36	800	8.9	56
	Eveleth	47.25	92.30	1376	9.4	3
	Fairmont	43.38	94.28	1161	8.9	86
	Falcon Hts	44.58	93.25	900	8.6	44
	Faribault	44.16	93.17	1054	8.5	104
	Fergus Falls	46.17	96.04	1510	8.8	87
	Hibbing	47.23	92.51	1352	9.2	95
	Little Falls	45.59	94.21	1118	8.5	76
	Mankato	44.04	93.58	1005	8.4	135
	Morris	45.35	95.55	1134	8.6	53
	Owatonna	44.06	93.14	1147	8.5	101
	Rochester	43.55	92.30	1310	8.8	242
	St. Peter	44.18	93.58	907	8.4	63
	Thief River Fall	48.04	96.11	1115	8.3	56
	Wadena	46.26	95.08	1350	8.5	50
	Worthington	43.37	95.36	1572	9.1	85
N. C:	Battleboro	36.01	77.46	107	10.3	3
	Belgrade	34.51	77.20	45	7.5	2
	Bishop	34.15	78.00	35	7.7	2
	Bolivia	34.05	78.12	39	7.2	3
	Bolton	34.18	78.25	45	7.9	3
	Bowdens	35.06	78.08	158	6.9	2
	Bridgeton	35.05	77.02	18	7.2	2
	Burgaw	34.25	77.55	40	7.8	4
	Calypso	35.09	78.07	163	8.3	2
	Castle Hay	34.18	77.50	30	8.6	3
	Cerro Gordo	34.18	78.56	60	8.3	1
	Chadbourn	34.18	78.52	65	7.3	3
	Chocowinity	35.30	77.04	10	7.9	4
	Delco	34.17	78.20	39	7.2	3
	Dixon	34.36	77.35	10	7.5	1
	Dudley	35.18	78.03	100	7.0	2
	Edenton	36.03	76.37	20	8.5	5
	Elizabeth	36.19	76.13	8	8.0	7
	Enfield	36.11	77.41	111	9.2	4
	Fair Bluff	34.18	78.79	60	7.1	3
	Faison	35.06	78.09	160	7.6	2
	Folkstone	34.33	77.40	10	6.9	1
	Freeman	34.18	78.22	42	7.9	1
	Fremont	35.43	77.59	104	9.2	3
	Garysburg	36.27	77.35	80	8.1	3
	Goldsboro	35.21	78.01	82	8.2	9
	Grissettown	34.10	78.40	20	6.8	2
	Halifax	36.21	77.38	91	8.4	3
	Hallsboro	34.18	78.38	55	8.0	1
	Hampstead	34.25	77.27	10	8.7	1
	Hartford	36.09	76.30	20	8.3	3
	Holly Ridge	34.30	77.60	10	6.6	3
	Jacksonville	34.45	77.24	14	7.2	5
	Junction route 301 and 11	35.43	77.56	145	9.6	1
	Kellum	34.48	77.22	35	8.6	2
	Lake Waccama	34.18	78.30	50	7.8	3
	Leland	34.15	78.05	30	7.1	2
	Macon	34.16	78.15	35	7.5	1
	Magnolia	34.35	78.04	154	7.2	3
	Maysville	34.50	77.18	44	7.2	3
	Morgans Corner	36.24	76.18	8	7.8	1
	Mt. Olive	35.12	78.04	165	7.9	5
	New Bern	35.05	77.02	18	7.5	6
	Odgen	34.22	77.31	13	6.5	1
	Pikeville	34.43	78.00	100	8.4	4
	Pollocksville	35.00	77.18	44	8.2	3
	Rhems	35.01	77.18	0	9.2	2
	Rocky Mount	35.58	77.48	104	10.8	14
	Rose Hill	34.39	78.02	151	7.6	5
	Scotts Hill	34.23	77.30	10	8.2	3
	Shallotte	34.00	78.27	40	7.6	4
	Sharpesburg	35.56	77.49	100	10.2	4
	South Mills	36.24	76.18	8	7.4	4
	Supply	34.03	78.24	39	7.3	2
	Vanceboro	35.19	77.03	14	9.0	4
	Verona	34.39	77.25	10	7.9	2
	Wallace	34.50	78.00	54	8.0	6
	Warsaw	35.04	78.08	157	7.6	5
	Weldon	36.26	77.36	81	9.1	2
	Whitakers	36.06	77.43	109	10.0	3
	Whiteville	34.19	78.43	61	7.6	4
	Williamston	35.51	77.02	10	8.4	8
	Wilmington	34.16	77.55	38	7.5	11
	Wilson	35.43	77.56	145	10.3	7
	Windsor	36.00	76.54	20	8.2	4
	Winnabow	34.14	78.05	39	7.4	2
	Woodville	36.08	77.10	50	7.7	1

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (µrad/hr)	Number of observations
N. H:	Concord	43.12	71.30	342	11.1	8
	Hampton Falls	42.50	70.50	50	9.6	4
	Hampton	42.53	70.47	50	10.0	4
	Henniker	43.08	71.50	375	10.1	4
	Keene	42.55	72.17	490	9.4	6
	North Branch	43.04	72.00	400	10.5	2
	Northwood	43.12	71.09	570	10.8	3
	Portsmouth	43.04	70.47	40	10.4	21
	Rochester	43.18	71.00	400	10.5	3
	Seabrook	42.48	70.53	50	9.7	4
	Smithtown	42.46	70.51	50	10.0	4
N. J:	Absecon	39.28	74.30	13	6.8	2
	Adams Station	40.17	74.42	50	10.0	2
	Atlantic City	39.27	74.26	11	7.4	3
	Bayville	39.54	74.10	5	7.6	2
	Bayonne	40.40	74.05	115	9.1	2
	Bricktown	40.03	74.02	10	7.2	3
	Barnegate	39.44	74.17	8	6.9	3
	Burleigh	39.04	74.52	10	7.7	2
	Cape May	39.08	74.50	10	7.1	6
	Cape May courthouse	39.08	74.50	10	7.4	4
	Cedar Run	39.39	74.19	8	6.5	1
	Clarksville	40.15	74.45	5	8.3	3
	Clermont	39.07	74.50	10	6.7	1
	Cowtown	39.40	75.20	50	7.8	3
	Delmont	39.13	74.50	35	6.9	4
	Dennisville	39.12	74.40	30	7.6	2
	Eastontown	40.20	74.05	10	7.0	3
	Elizabeth	40.40	74.14	40	9.6	5
	Elmer	39.36	75.10	90	7.6	5
	Forked River	39.50	74.13	10	6.8	4
	Goshen	39.10	74.52	15	7.2	2
	Jersey City	40.44	74.03	135	9.3	4
	Key Port	40.23	74.15	40	7.8	4
	Linden	40.38	74.15	30	9.5	3
	Linwood	39.26	74.34	10	7.2	2
	Malaga	39.35	75.04	60	6.5	3
	Manahawkin	39.40	74.18	8	7.2	2
	Marmora	39.17	74.40	10	6.6	3
	Middletown	40.20	74.08	30	7.9	3
	Millville	39.24	75.03	60	6.6	7
	Neptune	40.12	74.01	10	8.5	5
	New Bedford	40.07	74.02	10	8.0	3
	New Brunswick	40.28	74.26	86	10.8	6
	New Gretna	39.34	74.28	18	6.7	2
	Newark	40.42	74.10	11	9.3	5
	Northfield	39.27	74.33	12	7.1	3
	Oceanview	39.08	74.44	10	7.0	4
	Oceanville	39.29	74.28	15	7.1	3
	Oceanport	40.22	74.03	10	7.2	1
	Palermo	39.15	74.42	10	6.5	1
	Parkertown	39.37	74.20	16	6.6	1
	Penns Neck	40.16	74.44	52	9.5	3
	Perth Amboy	40.30	74.19	80	10.0	1
	Pine Beach	39.55	74.11	8	7.0	1
	Pleasantville	39.22	74.32	10	6.9	4
	Point Pleasant	40.05	74.02	10	7.0	5
	Port Elizabeth	39.20	74.55	40	6.4	2
	Rahway	40.36	74.16	20	10.1	2
	Red Bank	40.25	74.06	18	8.2	3
	Rio Grande	39.01	74.54	10	7.7	3
	South Dennis	39.12	74.51	15	7.0	2
	Sayreville	40.25	74.25	60	8.3	1
	Seaville	39.13	74.43	10	6.7	2
	Smithville	39.29	74.28	16	7.1	2
	Somers Point	39.20	74.34	10	7.0	2
	Staffordville	39.38	74.15	10	6.5	4
	Toms River	39.57	74.13	10	7.5	2
	Trenton	40.13	74.46	56	9.5	4
	Tuckertown	39.36	74.20	20	6.5	3
	Union City	40.42	74.08	120	10.7	2
	Vineland	39.28	75.03	60	6.7	3
	Wanamasser	40.13	74.01	10	7.6	3
	Waretown	39.45	74.15	8	7.0	3
	Whitesboro	39.02	74.53	10	7.1	2
	Woodbridge	40.35	74.20	100	8.2	1
	Woodstown	39.39	75.19	50	9.0	5
N. Y:	Auburn	42.54	76.32	715	9.4	7
	Avon	42.55	77.45	545	8.5	2
	Bellport Station	40.45	72.50	50	8.1	4
	Bethany	42.56	77.47	580	9.1	2
	Bronx	40.51	73.55	180	9.5	11
	Brooklyn	40.36	73.59	15	9.5	9
	Cazenovia	42.55	75.45	1000	8.9	4
	Commack	40.45	73.27	120	8.4	4

1115

Table 1. Average values of backgrou[illegible]ma dose rate measurements using portable gamma s[illegible]ounters—continued

State and city		[illegible]e	Longitude	Altitude	Average (μrad/hr)	Number of observations
N. Y:	Centereach	40.59	73.04	50	8.4	3
	Darian	42.57	77.50	600	9.8	2
	Depew	42.58	70.35	700	9.8	2
	Duanesburg	42.45	74.15	500	9.6	4
	East Quogue	40.51	72.00	80	8.1	3
	Eastport	40.46	72.40	60	7.5	3
	Fredonia	42.25	79.18	760	9.7	4
	Geneva	42.53	77.00	590	9.2	4
	Hampton Bay	40.58	71.45	100	8.0	4
	Huntington	40.45	73.30	120	8.9	5
	Jericho	40.51	73.25	100	8.3	7
	La Fayette	42.54	76.08	500	9.2	2
	Lancaster	42.58	78.33	705	9.1	2
	Madison	42.55	75.30	900	9.0	4
	Manhattan	40.47	74.58	132	8.7	12
	Middle Isle	40.59	72.58	50	7.9	2
	Oyster Bay	40.50	73.35	100	8.9	2
	Patchoque	40.45	73.03	30	7.7	4
	Portland	42.20	79.29	800	9.3	2
	Potter Hill	42.50	73.43	250	11.0	3
	Queens	40.39	73.47	13	9.1	5
	Richfield	42.45	75.03	875	9.3	4
	Ridge	40.59	72.55	50	7.4	1
	Ripley	42.03	79.50	985	9.5	4
	Riverhead	40.58	72.43	100	7.6	4
	South Buffalo	42.53	78.45	700	10.9	1
	Schnectady	42.50	73.55	225	8.9	9
	Seldon	40.59	73.01	50	7.7	3
	Seneca Falls	42.54	76.50	460	8.9	6
	Sharon	42.45	74.50	800	9.2	3
	Silver Creek	42.30	79.10	730	10.0	3
	Smithtown	40.46	73.20	100	8.5	3
	Staten Island	40.36	74.10	80	9.2	10
	Troy	42.50	73.45	24	10.3	9
	Wading River	40.59	72.48	50	9.3	3
	West Avon	42.55	77.45	545	8.5	1
	West Bloomfield	42.54	77.30	545	8.2	1
	West Canadaiqua	42.54	77.15	580	8.9	4
	West Hampton	40.45	72.15	70	8.6	3
	Westfield	42.17	79.37	975	9.5	2
Ohio:	Columbus	40.00	82.53	812	10.8	1
	Darlington	40.30	82.35	790	9.9	1
	Pleasant Home	40.50	82.10	740	9.9	1
	Willoughby	41.41	81.24	612	10.1	1
Pa:	Austinberg	42.00	77.32	1590	9.7	2
	Concordville	39.45	75.30	50	9.8	2
	Elam	39.42	75.32	60	9.9	2
	Erie	42.05	80.11	732	10.1	1
	Media	39.50	75.28	45	11.9	2
	Morrisville	40.15	74.48	50	9.4	2
	Oxford Valley	40.13	74.52	48	10.1	2
	Penndel	40.10	75.00	40	11.2	4
	Philadelphia	39.57	75.11	30	10.8	30
	Upper Darby	39.57	75.15	35	10.2	6
R. I:	Clayville	41.45	71.50	50	10.1	3
	Providence	41.44	71.26	51	9.6	42
	Rice City	41.41	71.53	50	9.7	3
	Vernon	41.43	71.52	50	11.1	3
S. C:	Allendale	33.00	81.20	200	8.4	8
	Ashepoo	32.40	80.30	9	8.5	3
	Awendaw	32.55	79.35	10	7.4	4
	Bamberg	33.17	81.03	165	8.1	6
	Bowman	33.18	80.42	100	7.7	5
	Byrds	33.10	80.33	100	7.6	1
	Charleston	32.47	79.54	9	10.0	14
	Coosahatch	32.30	80.53	53	7.9	3
	Dorchester	33.08	80.30	95	8.3	2
	Effingham	34.04	79.45	58	7.7	2
	Florence	34.13	79.46	144	8.0	7
	Gable	33.46	80.10	80	7.9	1
	Garden City Beach	33.41	78.55	10	9.1	2
	Gardens Corner	32.32	80.28	40	9.0	2
	Georgetown	33.22	79.17	14	7.2	11
	Hardeeville	32.15	80.58	40	8.6	7
	Jacksonboro	32.43	80.25	9	8.4	3
	Jedburg	33.05	80.25	90	8.9	1
	Litchfield	33.29	79.03	12	7.6	3
	Little River	33.53	78.40	15	7.1	3
	Manning	33.42	80.14	95	8.0	5
	Marion	34.11	79.24	68	8.1	5
	McClellanville	33.05	79.28	10	7.2	4
	Mount Pleasant	32.45	79.50	10	8.1	5
	Mullins	34.13	79.18	50	7.7	4

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (µrad/hr)	Number of observations
S. C:	Murrells Inlet	33.30	79.01	10	6.8	3
	Myrtle Beach	33.43	78.48	15	7.6	5
	Nichols	34.15	79.10	40	6.8	3
	Ocean Drive Beach	33.51	78.42	15	6.6	4
	Olanta	33.53	79.55	60	7.8	4
	Pee Dee	34.12	79.32	60	8.0	2
	Pawleys Island	33.25	79.08	12	7.0	3
	Orangeburg	33.30	80.52	244	9.1	6
	Pocataligo	32.32	80.48	50	8.9	2
	Pregnall	33.09	80.32	100	8.1	1
	Rantowles	32.45	80.15	9	8.9	4
	Ridgeland	32.28	80.58	57	8.1	4
	Ridgeville	33.14	80.45	90	10.5	3
	Rosinville	33.12	80.40	105	7.6	2
	Santee	33.13	80.42	100	8.7	7
	Sardinia	33.48	80.02	80	8.2	2
	Sheldon	32.31	80.45	45	8.7	2
	South Carolina line	32.56	81.02	200	8.2	1
	St. George	33.11	80.34	109	9.3	4
	Summerton	33.35	80.18	90	8.4	4
	Summerville	33.02	80.12	75	7.8	3
	Surfside	33.40	78.50	10	8.0	4
	Turbeville	33.50	80.01	70	6.3	3
	Ulmers	33.10	81.15	200	8.1	6
	Windy Hill	33.45	78.45	15	7.3	4
Tenn:	Chattanooga	35.02	85.12	665	9.8	7
	Dayton	35.30	85.01	810	9.0	3
	East Ridge	35.01	85.20	650	9.3	2
	Elgin	36.20	84.39	1475	9.6	1
	Evansville	35.40	84.58	850	8.9	1
	Georgia and Tennessee line	35.00	85.25	650	9.1	1
	Glenmary	36.18	84.41	0	9.9	1
	Graysville	35.25	85.05	750	10.6	1
	Harrimans	35.58	84.35	935	9.3	1
	Isham	36.55	84.27	1400	9.2	1
	Lancing	36.09	84.41	1480	8.9	1
	New River	36.25	84.37	1450	10.3	2
	Oneida	36.30	84.31	1450	9.5	2
	Robbins	36.24	84.39	1460	10.6	2
	Rockwood	35.52	84.41	930	9.3	3
	Sale Creek	35.20	85.06	700	9.1	1
	Spring City	35.47	84.55	900	8.5	1
	Sunbright	36.14	84.42	1495	9.9	1
	Wartburg	36.08	84.40	1450	10.0	1
	Winfield	36.34	84.27	1425	8.8	1
Vt:	Bennington	42.55	73.13	670	9.5	7
	Brattleboro	42.45	72.35	300	8.6	4
	Wilmington	42.55	73.13	400	9.2	4
Va:	Accomac	37.45	75.38	20	8.3	4
	Alexandria	38.48	77.05	70	9.1	6
	Arlington	38.50	77.05	70	9.0	10
	Capron	36.44	76.30	35	7.9	2
	Carmel Church	37.40	77.21	90	8.7	2
	Charles City	37.22	77.05	100	8.9	4
	Chesepeake	36.25	76.20	10	8.0	3
	Cheriton	37.17	75.58	11	7.0	1
	Dreweryville	36.42	76.31	50	8.4	2
	Dumfries	38.32	77.20	100	10.2	2
	Eastville	37.20	75.55	15	6.9	1
	Engleside	38.43	77.13	220	8.9	2
	Emporia	36.41	77.33	80	10.0	8
	Exmore	37.33	75.50	32	7.9	3
	Fredricksburg	38.18	77.28	20	9.3	6
	Golansville	37.45	77.23	85	7.8	2
	Groveton	38.46	77.06	245	8.9	2
	Gum Tree	37.35	77.21	100	8.9	4
	Hampton	37.03	76.23	20	8.5	7
	Kiptopeke Beach	37.13	76.00	10	8.0	2
	Ladysmith	37.50	77.24	80	7.8	3
	Machipongo	37.25	75.53	25	7.3	1
	Massaponax	38.00	77.26	55	8.6	3
	Nassawa Dox	37.28	75.52	35	7.8	2
	Nelsonia	37.48	75.35	18	8.8	2
	New Church	37.56	75.22	10	8.6	3
	Newport News	36.59	76.26	25	8.9	8
	Norfolk	36.56	76.00	26	7.9	9
	Oak Hill	37.55	75.25	14	8.7	2
	Onley	37.43	75.40	25	7.9	2
	Painter	37.35	75.49	30	8.1	2
	Pohick	38.42	77.16	210	9.2	1
	Richmond	37.30	77.20	162	9.2	14
	Skippers	36.38	77.33	80	9.7	2
	Stafford	38.20	77.23	15	8.7	4
	State Park	36.52	76.06	20	8.0	3

150

Table 1. Average values of background gamma dose rate measurements using portable gamma scintillation counters—continued

State and city		Latitude	Longitude	Altitude	Average (µrad/hr)	Number of observations
Va:	Tasley	37.44	75.39	22	7.6	1
	Temperance	37.53	75.30	16	8.4	2
	Thornburg	37.55	77.25	70	8.9	3
	Triangle	38.30	77.21	12	9.3	1
	Virginia & North Carolina Line	36.36	77.33	80	8.8	1
	Virginia Beach	36.51	76.00	16	7.6	3
	Williamsburg	37.18	76.42	70	8.1	6

Iodine-131 in Bovine Thyroids, April-June 1968

National Center for Radiological Health
Public Health Service

The National Center for Radiological Health established a Bovine Thyroid Network in October 1964 (*1*). Specimens are collected by the Livestock Slaughter Inspection Division, U.S. Department of Agriculture, and are analyzed by gamma-ray spectroscopy for iodine-131 content at the Northwestern Radiological Health Laboratory, Winchester, Mass.

The network consists of collection areas (countries shaded in figure 1) located so as to cover, as nearly as possible, areas near major nuclear reactors, spent fuel reprocessing plants and nuclear test sites. Details of sampling and analyses have been published earlier (*1*).

The results for April through June 1968 appear in table 1 and are listed chronologically within each State. The iodine-131 levels in thyroids of all samples collected during this period were not above the barely detectable level of 2 to 5 pCi iodine-131/g thyroid except for one sample collected May 10, 1968, in Walla Walla, Wash. (7pCi iodine-131 g thyroid).

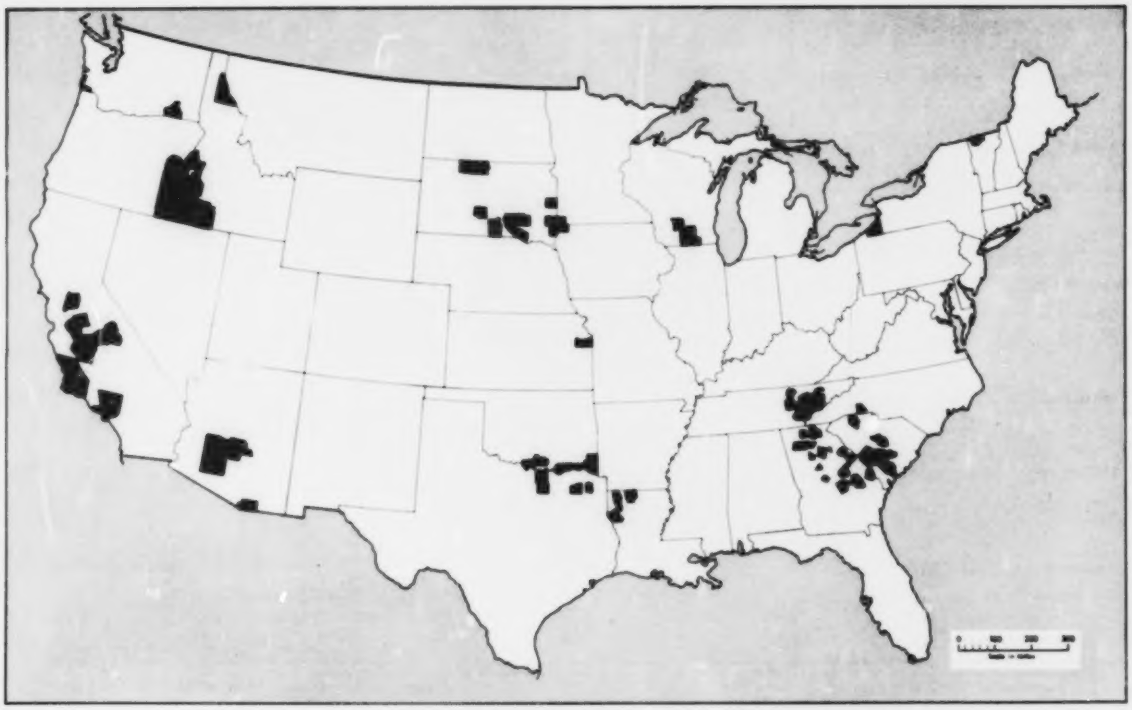

Figure 1. Counties sampled in Bovine Thyroid Network, April–June 1968

REFERENCE

(*1*) BARATTA, E. J., E. R. WILLIAMS, and G. MURRAY. Iodine-131 in bovine thyroids, October–December 1964. Radiol Health Data 6:569–571 (October 1965).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1967	May 1968
January–March 1968	August 1968

Table 1. Iodine-131 in bovine thyroids, April–June 1968

State	Dates of slaughter	County	Number of samples	Average concentration
				pCi iodine-131/g thyroid
Arizona	4/3	Maricopa	1	ND
	4/11		1	2
	[a]4/17–6/27		12	ND
	5/1	Pinal	1	ND
California	[a]4/20–6/26	Merced (1) [c] Monterey (7) San Benito (15) San L. Obisco (3) Santa Clara (3)	29	ND
Georgia	[a]4/9 –6/26	Bartow (5) [c] Bibb(8) Burke (3) Butts (2) Candler (4) Clarke (6) Dodge (2) Evans (2) Forsyth (8) Fulton (5) Greene (4) Jenkins (6) Laurens (2) McDuffie (6) Richmond (1) Screven (9) Thomas (2) Upson (2) Warren (6) Wilkes (13)	96	[b] ND
Idaho	4/8	Canyon	5	ND
Iowa	4/1	Lyon	8	ND
	5/9	Lyon	7	ND
Kansas	4/23–4/24	Douglas	2	ND
Louisiana	[a]5/3 –6/20	Claiborne (1) [c] Natchitaches (2) Red River (1)	4	ND
Minnesota	5/21	Rock	4	ND
	6/12	Lincoln	1	ND
Mississippi	[a]6/17–6/25	Forrest (1) [c] Hinds (1) Jackson (1) Jones (2) Lauderdale (7) Marion (1)	13	ND
Nebraska	6/10	Platte (2) [c] Sanders (1)	3	ND
New York	[a]4/3 –6/18	Cattaraugus (10) [c] Chautaugua (40)	50	ND
North Carolina	4/2	Cleveland	4	ND
Oklahoma	[a]4/2 –6/19	Bryan (1) [c] Carter (7) Choctaw (1)	9	ND
South Carolina	[a]4/2 –6/26	Bamberg (5) [c] Barnwell (4) Edgefield (1) Greenwood (4) McCormick (2) Orangeburg (3) Saluda (2)	21	[b] ND
South Dakota	[a]4/1 –6/26	Aurora (10) [c] Brookings (7) Brule (1) Clark (11) Faulk (3) Grant (2) Gregory (1) Hanson (3) Hamlin (1) Kingsbury (7) Lake (3) Minnehaha (6) Roberts (8) Tripp (7) Turner (1)	71	[b] ND
Tennessee	[a]4/3 –6/25	Blount (1) 0[c] Knox (5) Loudon (2) Sevier (2) Union (1)	20	[b] ND
Texas	[a]4/1 –6/24	Bowie (1) [c] Cass (2) Cooke (1) Denton (6) Hopkins (2) Titus (2)	14	ND
Vermont	[a]4/24–6/18	Franklin	52	ND
Washington	[a]5/6 –6/28	Walla Walla	23	ND
	5/10	Walla Walla	1	7
Wisconsin	[a]4/12–6/28	Dane (30) [c] Green (1) Portage (6) Rock (13)	50	ND

---

[a] Samples were not collected on all dates during this period, but the interval includes several sampling dates.

[b] The results for this period were for the most part, not detectable. Some randomly scattered positive results were obtained; but these represented barely detectable amounts of iodine-131 in the bovine thyroid (2 to 5 pCi/g).

[c] Numbers in parentheses represent the number of samples collected from that county during the interval indicated. These may have been collected over several dates during the period or on only one date.

Radionuclides in Washington Shellfish[1], January 1963-December 1967

Washington State Department of Health

As part of their surveillance of radioactivity in the environment, the Washington State Department of Health routinely collects oysters and clams for analysis. These shellfish have the ability to concentrate radionuclides such as phosphorus-32 and zinc-65, attaining levels far above the ambient concentrations present in the water.

Samples from the Washington coast and the Olympia and Dabob Bay areas of Puget Sound are collected by the Food Protection Section of the Washington State Health Department. Those from the Bangor Naval Ammunition Depot are collected by the U.S. Navy and sent to the State Health Department through the Kitsap-Bremerton Health District, which also collects the samples from the Bremerton area.

Shells are removed in the laboratory. The supernatant liquid is decanted and the entire edible portion is homogenized and placed in a 1-pint cottage cheese container for analysis on the multichannel analyzer. Four hundred grams of sample are analyzed when available. After the gamma analysis, phosphorus-32 separation is performed by a modification of techniques described in the literature (*1–4*). Twenty-five grams of the homogenized sample are completely ashed using dry and wet ashing techniques. The total ash is treated with hydrofluoric acid to dissolve any silicates present, and after complete removal of excess hydrofluoric acid, the sample is dissolved in $3\underline{N}$ nitric acid. Ammonium nitrate is added to give 5–10 percent in the final solution. A large excess of ammonium molybdate is then added and the sample left overnight to insure complete precipitation of the phosphorus as ammonium phosphomolybdate.

Interfering ions are also precipated and must be removed. The precipitate is washed with a 5 percent solution of ammonium nitrate, then dissolved in $6\underline{N}$ ammonium hydroxide containing 0.5 g citric acid. The citric acid will complex most interfering ions. To this solution, magnesia mixture (containing magnesium chloride and ammonium chloride) is added to precipitate the phosphorus as magnesium ammonium phosphate. After standing overnight, the alkaline filtrate is discarded and the precipitate washed thoroughly with 1:20 ammonium hydroxide. It is then dissolved in warm, very dilute hydrochloric acid. The magnesia precipitation is repeated, but from an acid solution to insure complete and final separation from interfering elements. After standing overnight to insure complete precipitation, the precipitate is filtered off, washed thoroughly with 1:20 ammonium hydroxide and transferred, using $3\underline{N}$ nitric acid, to a weighed stainless steel planchet. After drying in an oven at 110°C, the sample is submitted for counting of the beta radioactivity.

Table 1 lists results of all oyster samples arranged according to collection area and collection date. Quantitative results extrapolated to date of collection for ruthenium–106, zirconium–95, zinc–65, potassium–40, and phosphorus–32 are included for the period July 1964 through December 1967. Results of clam samples (which were collected only in Puget Sound) have been omitted from table 1 since all data other than potassium–40 was below the respective detectability limits.

To illustrate trends occurring in oysters from the Washington coast, data from past years have been presented in graphic form in figures 1 and 2. Figure 1 shows zinc–65 and phosphorus–32 concentrations in oysters collected from Stony Point in Willapa Bay during the

---

[1] Summarized from the annual and quarterly reports of the Washington State Department of Health.

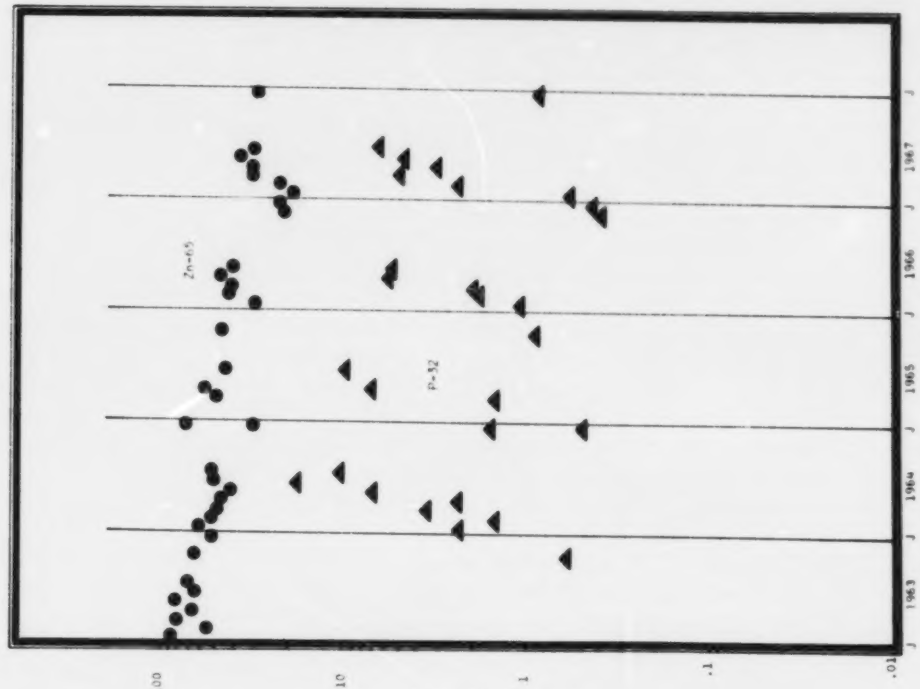

Figure 1. ^{65}Zn and ^{32}P in Willapa Bay oysters, Stony Point

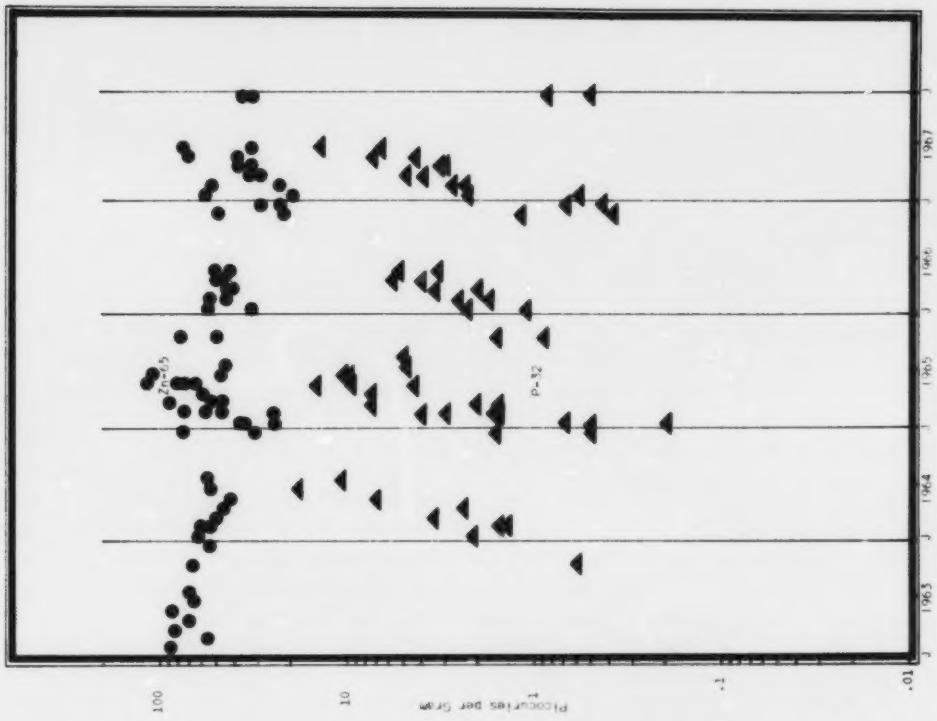

Figure 2. ^{65}Zn and ^{32}P in Willapa Bay oysters, all stations

154

Table 1. Oyster analyses, July 1964 through December 1967

Collection date	Location	Year [a]	Concentration (pCi/g wet weight) [b]				
			Phosphorus-32	Potassium-40	Zinc-65	Zirconium-95	Ruthenium-106 [c]
	PUGET SOUND						
1964							
July 30	Oyster Bay	1961	<0.03	2.0	0.2	<0.03	<0.3
1965							
April 22	Oyster Bay	1962	<.03	1.7	.3	<.03	<.3
1966							
January 15	Dabob Bay	1960-61	<.03	1.6	1.1	<.04	<.3
February 28	Dabob Bay	1960-61	<.03	2.2	1.1	<.04	<.3
March 17	Bangor	Natural Set.	<.03	1.8	1.0	<.04	<.3
April 9	Dabob Bay	Unknown	<.03	1.9	1.0	<.04	<.3
April 19	Bangor	Natural Set.	<.03	2.3	1.0	<.11	<.8
April 19	Dungeness	Unknown	<.03	2.3	2.3	<.04	<.3
April 27	Olympia	Unknown	<.03	2.0	.2	<.04	<.3
May 18	Bangor	Natural Set.	<.03	2.4	1.2	.05	.4
June 16	Bangor	Natural Set.	<.03	2.3	1.0	<.07	<.6
July 20	Bangor	Unknown	<.03	1.9	.7	<.08	<.6
August 29	Bangor	Unknown	<.03	2.2	.7	<.08	<.6
September 29	Bangor	Unknown	<.03	2.2	.6	<.06	<.5
1967							
January 3	Olympia	1958	<.03	2.1	.2	NA	NA
January 15	Olympia	1958	<.03	2.0	.1	<.020	<.25
February 22	Bangor	Natural	<.03	1.6	.8	<.050	<.63
March 15	Bangor	Natural	<.03	1.8	.7	<.026	<.23
April 27	Bangor	Natural	<.03	2.0	.6	<.034	<.43
May 24	Bangor	Natural	<.03	1.3	.6	<.026	<.33
June 21	Bangor	Natural	<.03	2.0	.7	<.034	<.42
April 18	Dabob Bay	Natural	<.03	2.1	.5	<.032	<.40
April 27	Olympia	1958	<.03	2.2	.1	<.020	<.25
August 17	Bangor	Natural	<.03	2.7	.67	<.050	<.63
July 20	Bangor	Natural	<.03	1.7	.57	<.032	<.40
December 18	Lt. Skookum Bay	1963	<.03	2.3	.23	<.020	<.25
	GRAYS HARBOR						
1964							
July 28	Ocosta	Unknown	10.0	2.1	46	<.03	.4
December 3	Ocosta	Unknown	.2	1.7	16	<.03	<.3
1965							
January 13	Ocosta	1962	.4	1.7	37	<.03	.4
February 25	Ocosta	1962	1.3	1.2	35	<.03	<.3
July 29	Ocosta	Unknown	.6	2.4	10	<.04	<.3
October 28	Ocosta	Unknown	.6	2.1	19	<.05	<.4
November 18	Grass Creek	1963	.9	1.6	27	<.04	<.3
1966							
January 18	Ocosta	Unknown	1.4	1.5	26	.04	<.3
February 7	Ocosta	Unknown	.9	2.0	22	<.04	<.3
April 10	Ocosta	Unknown	2.3	2.0	29	<.04	<.3
November 15	Ocosta	Unknown	.20	2.6	16	<.04	<.30
December 16	Ocosta	1962	.48	2.0	14	<.04	<.30
1967							
January 16	Ocosta	Unknown	.52	1.3	16	<.020	.37
February 25	Ocosta	Unknown	.60	1.2	15	.061	.25
March 23	Ocosta	1964	3.39	1.5	28	.022	.25
April 17	Ocosta	1964-65	2.07	1.8	29	<.020	<.25
May 12	Ocosta	1964	2.77	2.1	35	<.020	<.25
June 27	Ocosta	1964	3.87	1.9	30	.023	1.03
December 11	Manard	Unknown	.50	1.6	18	<.020	<.25
	WILLAPA BAY						
1964							
July 28	Stony Point	Unknown	10.6	1.7	54	.06	1.0
December 4	Stony Point	1961	1.6	1.8	75	.07	.4
December 4	Stony Point	1963	.5	1.7	31	<.03	<.3
1965							
January 14	No. River Fl.	1958	.2	1.5	24	<.03	<.3
January 14	No. River Fl.	1962	.7	1.4	36	.04	<.3
January 14	Bay Center	1962	.5	1.5	34	.04	<.3
February 25	Oysterville	1961	3.0	1.7	55	<.03	.4
February 25	No. River Fl.	1962	1.5	1.6	24	<.03	<.3
February 25	Stackpole	1961	4.2	2.2	72	<.03	<.3
February 25	Oysterville	1961	1.6	1.9	45	<.03	.6
March 23	Stackpole	1961	7.3	2.3	85	.10	<.3
March 23	Stony Point	1962	1.5	1.9	51	.06	<.3
March 23	Bay Center	1961	2.1	1.6	45	.03	.4
April 21	Stony Point	1962	7.2	1.8	58	.04	<.3
May 18	Bay Center	1959	9.7	2.0	72	.05	.5
May 18	Long Island	Unknown	4.3	2.5	63	<.03	.8
May 18	Nemah Flats	1962	14.7	2.2	78	<.03	<.3
May 18	Stackpole	Natural	14.9	1.9	114	.04	<.3

See footnotes at end of table.

Table 1. Oyster analyses, July 1964 through December 1967—Continued

Collection date	Location	Year [a]	Concentration (pCi/g wet weight) [b]				
			Phosphorus-32	Potassium-40	Zinc-65	Zirconium-95	Ruthenium-106 [c]
	WILLAPA BAY						
1965							
June 16	Stackpole	1962	10.4	2.3	106	<.04	.8
June 16	Stony Point	1961	9.7	1.8	46	<.04	.9
July 27	Oysterville	1962	4.9	2.5	43	<.04	<.3
August 24	Stackpole	1962	5.1	NA	NA	NA	NA
October 10	Stackpole	Unknown	1.6	2.2	76	<.04	<.3
October 28	Stony Point	1962	.9	1.9	49	.05	<.3
1966							
January 18	Stackpole	Unknown	2.3	2.0	53	<.04	<.3
January 18	Stony Point	Unknown	1.1	1.8	31	.05	<.3
February 8	Stony Point	1962-63	1.8	2.4	43	<.04	<.3
February 9	Oysterville	Unknown	2.6	2.0	53	<.04	<.3
March 30	Oysterville	1963	3.4	1.8	40	.04	<.3
March 30	Stony Point	1962	2.0	2.1	42	.05	<.3
April 11	Oysterville	Unknown	4.1	2.2	44	.09	<.3
April 10	Stony Point	Unknown	5.6	1.8	48	.08	<.3
May 18	Stony Point	1963	5.4	2.0	41	<.04	<.3
May 19	Oysterville	Unknown	3.3	2.3	50	<.04	<.3
November 15	Stony Point	1964	.40	1.6	21	<.02	<.30
November 16	Stackpole	Unknown	1.23	1.8	48	<.02	<.30
December 15	Stackpole	1962-63	.70	1.6	29	.026	<.30
December 19	Stony Point	1964	.45	1.7	22	<.02	<.30
1967							
January 18	Stackpole	1960-64	2.30	1.7	57	.031	.75
January 18	Stony Point	1964	.58	1.8	19	<.020	.53
February 25	Stackpole	1963-65	2.82	2.3	51	<.020	.46
February 26	Stony Point	1963-64	2.41	1.5	23	<.020	.28
March 28	Stony Point	1965	4.94	1.6	32	<.020	.28
March 28	Oysterville	1964	4.03	1.7	29	.026	.32
April 18	Stackpole	1963-64	2.99	1.9	38	<.020	<.25
May 16	Stackpole	1963-64	7.34	2.1	70	.033	<.25
June 27	Stackpole	1964	14.26	2.3	74	.026	<.25
April 19	Stony Point	1965	3.12	1.5	32	<.020	.43
May 17	Stony Point	1964	4.45	1.8	39	.027	.77
June 27	Stony Point	1964	6.48	1.9	32	<.020	.27
December 11	Oysterville	1962	.52	1.9	35.87	<.020	<.25
December 11	Stony Point	Unknown	.86	1.7	30.46	<.020	<.25

[a] Planting year of oyster seed in growing beds.
[b] All results extrapolated to date of collection.
[c] Net radioactivity in the 0.44–.56 MeV gamma range, computed as ruthenium-106.
NA, no analysis performed.

period January 1963 through December 1967. Various factors inherent in the data preclude defining specific trends. The total number of samples is small, and a three-fold variation has been found between oysters taken from the same growing beds. A complete history of each sample is often unknown, and the residency time in a specific growing bed has varied from a few months to more than 3 years. Some oysters are seeded in Puget Sound, later moved to Willapa Bay, and then moved once again before harvesting.

Figure 2 is a graph of zinc–65 and phosphorus–32 concentrations for all oyster samples collected in Willapa Bay. In addition to the variables discussed above there are apparent differences in isotope concentrations due to location of the growing beds within the bay. These variables influence interpretation of trends in the data, but figures 1 and 2 still show an increase in phosphorus–32 levels each spring with a corresponding decrease in the fall and winter. This would result from ocean currents carrying the Columbia River effluent southward in the summer and northward in the winter. The short half-life of phosphorus–32 causes varying concentrations with exposure while there would be little change seen in the longer half-life zinc–65.

REFERENCES

(*1*) KOLTHOFF and SANDELL. Textbook of Quantitative Inorganic Analysis, Revised Edition. The McMillan Company, New York (1949) pp. 390–397 and 713–717.

(*2*) HILLEBRAND, W. F., and G. LUNDELL. Applied Inorganic Analysis. John Wiley and Sons, Inc., New York (1953) pp. 694–710.

(*3*) FURMAN, N. H., Editor. Scott's Standard Methods of Analysis, 5th Edition, Vol. I. Van Nostrand Company, Inc., New York (1944) pp. 694–697.

(*4*) HANFORD WORKS. Radiological Chemical Analysis: Environmental Analysis Manual—Phosphorus–32 in Edibles. Hanford Works, Richland, Washington.

Environmental Levels at Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major AEC installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the AEC Manual.[1]

Summaries of data from the environmental radioactivity monitoring reports follow for the Los Alamos Scientific Laboratory and Rocky Flats Plant.

---

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation," contains essentially the standards published in Chapter 0524 of the AEC Manual.

---

1. Los Alamos Scientific Laboratory [2]

Calendar year 1967

University of California
Los Alamos, New Mexico

As part of the environmental monitoring program at Los Alamos, measurements of beta radioactivity in airborne particulates and precipitation, are made periodically. The samples have been taken on the roof of building TA–50 (about 1¾ miles southeast of the Administrative Building) since March 1963.

Air monitoring

Airborne radioactive particulate matter is collected on 4-inch-diameter filters. The sampling rate was reduced from 46 m^3/hr in 1962 to 25.5 m^3/hr in 1963, due to the addition of an activated charcoal filter behind the first filter. Air samples are ordinarily collected for 24-hour intervals during the work week, and weekend samples are collected for a 72-hour period.

The filters are counted for beta radioactivity 7 days after collection in a thin-window (methane) flow proportional counter with an overall efficiency for strontium-yttrium–90 of 50 percent.

In September 1966 a large chamber was added to the "Sharp Widebeta Counting System" that permits the counting of these air samples in the same geometry as the precipitation samples. The efficiency for strontium-yttrium–90 remains the same as in the older counter.

Precipitation monitoring

Collection is made in a 0.4 square meter rain collector which delivers 1 liter of water for each 0.1 inch of precipitation. It has been found that this arrangement collects radioactivity even during relatively dry periods. By washing down the sides of the collector with 1 liter of distilled water, a suitable sample is obtained.

---

[2] Summarized from "Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1967" (LA–3887).

These "wash" samples, as well as any precipitation, are reduced in volume, dry-plated on 1-inch stainless steel planchets, and counted in an automatic beta-particle counting system. This system has a gas-flow proportional counter, which provides increased efficiencies and lower background than previous systems.

Results

Average daily radioactivity concentrations for air collected are weighted for sample periods of more than 1 day. Average radioactivity concentrations for the precipitation collection are calculated from the total radioactivity collected during the month divided by the number of days in the month. Summary of the daily air data (pCi/m^3) shows the maximum was 2.67, minimum less than 0.01; and the average 0.037. The precipitation data (nCi/m^3) shows the maximum was 32.7; minimum 0.003; and the average 0.16.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
Calendar year 1966	December 1967

---

2. Rocky Flats Plant [3]
January–June 1968

Dow Chemical Company
Golden, Colorado

The Rocky Flats Plant (RFP) is engaged in routine production operations involving plutonium and uranium under contract to the Atomic Energy Commission. Its location, relative to population centers, is shown in figure 1. To assure properly controlled release of radioactive materials to the environment, periodic samples of air, water, and vegetation are analyzed for gross alpha radioactivity. The most abundant radioactive material involved in the process is plutonium.

The plant is located about 15 miles northwest of Denver. The surface stratum in this area consists of gravel washed out of the highly mineralized front range of the Rocky Mountains, where heterogeneous low-level deposits of uranium, thorium, and radium exist in the soil. These materials are measurable in most samples of air, water, and vegetation.

Air

Continuous air samples were collected at Coal Creek Canyon, Marshall, Boulder, Lafayette, Broomfield, Wagner School, Golden, Denver, and Westminster. The monthly average long-lived gross alpha radioactivity shown in table 1 are believed to result from naturally occurring materials. All values are less than

Table 1. Long-lived gross alpha radioactivity in airborne particulates, RFP environs, January–June 1968

Period (1968)	Average concentration (pCi/m^3)
January	0.3×10^{-3}
February	2.2×10^{-3}
March	0.5×10^{-3}
April	0.5×10^{-3}
May	0.3×10^{-3}
June	0.7×10^{-3}

---

[3] Summarized from "Environmental Survey, January–June 1968," The Dow Chemical Company, Rocky Flats Division, Golden, Colo.

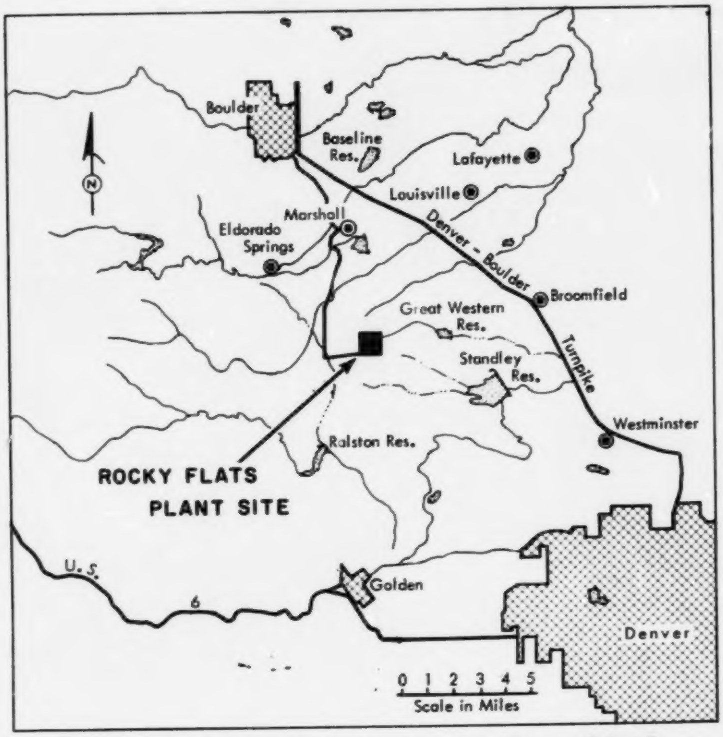
Boulder
Baseline Res.
Lafayette
Louisville
N
Marshall
Eldorado Springs
Denver - Boulder Turnpike
Broomfield
Great Western Res.
Standley Res.
Westminster
Ralston Res.
ROCKY FLATS PLANT SITE
U.S. 6
Golden
Denver
0 1 2 3 4 5
Scale in Miles

Figure 1. Rocky Flats Plant and environs near Denver, Colorado

the AEC standard of 0.04 pCi/m^3 for mixtures of unidentified radionuclides.

Water

Regular water samples were obtained monthly except during the winter months from four reservoirs in the area of the Rocky Flats Plant. The results of alpha radioactivity analyses performed on these samples are given in table 2. The analytical results for water samples obtained during the summer collection period from outlying streams and lakes during the July collection period will be tabulated in the next report. For comparison purposes, the AEC standard for mixtures of unidentified radionuclides in water is 10 pCi/liter.

Table 2. Alpha radioactivity in water, RFP environs January–June 1968

Reservoir	Number of samples	Average concentration (pCi/liter)
Great Western	4	2.3
Standley	4	1.3
Baseline	5	1.2
Ralston	5	4.2

Vegetation

During this period, January–June 1968, no vegetation samples were collected. Additional samples collected in October 1967 and not previously reported are presented in table 3.

Table 3. Alpha radioactivity in vegetation RFP environs, October 1967

Collection period (1967)	Distance from plant	Number of samples	Average concentration (pCi/kg dry weight)
October 1967	Less than 3 miles	21	120
October 1967	3 to 18 miles	40	118

Recent coverage in ***Radiological Health Data and Reports:***

Period	Issue
January–June 1967	January 1968
July–December 1967	May 1968

Reported Nuclear Detonations, October 1968

The U.S. Atomic Energy Commission announced a nuclear test of low yield (20 kilotons or less TNT equivalent) was conducted underground at its Nevada Test Site on October 3, 1968.

160

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

WHOLE BODY CESIUM-137 AND ITS RELATION TO BODY COMPOSITION AND DIET. *R. C. Steinkamp, T. W. Sargent, E. Isaacs, N. L. Cohen, E. M. Hutson, and N. D. Kunkel. Radiological Health Data and Reports, Vol. 9, November 1968*, pp. 619–626.

Between September 1962 and July 1963, a time of rising cesium-137 content in the biosphere, whole body cesium-137 and potassium-40 measurements were performed in an Argonne-type scintillation counter on 80 subjects; 52 men and 28 women. These data have been correlated with body composition estimates of body fat and lean body mass. Seventy-eight of the subjects had diet interviews. The intakes of food categories were correlated with *in vivo* cesium-137 measurements. The results suggest that calculations of dose rates for cesium-137 may be more meaningful if based on lean body mass rather than total body weight, as is done presently.

Intakes of milk, fruits and vegetables correlated significantly with *in vivo* cesium-137 measurements for those subjects with extremely low or extremely high food intakes. A regression equation was determined to calculate pCi cesium-137/g potassium in people from pCi cesium-137/g potassium in milk. There appeared to be a time lag of 4 to 5 months between rising values of cesium-137 in milk and those in people, consistent with the biological half-life of cesium-137.

KEYWORDS: body burden, cesium-137, diet, dose rate, humans, milk, potassium-40.

161

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 9, Number 12, December 1968

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the National Center for Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

Department of Defense
Department of the Interior
Department of Agriculture
Department of Commerce
Department of Health, Education, and Welfare
Atomic Energy Commission

CONTENTS

Page

REPORTS

Cesium-137 Concentrations in Alaskans during the Spring of 1967 705
H. J. L. Rechen, R. L. Mikkelsen, O. G. Briscoe and *J. F. Steiner, Jr.*

TECHNICAL NOTES

Alpha Radiation Exposure Levels in Underground Uranium and Other Mines 719
Bureau of Mines

Alpha Radioactivity in Coal Mine Drainage in Western Pennsylvania 725
R. D. Caldwell, R. F. Crosby, and *M. P. Lockard*

DATA

SECTION I. MILK AND FOOD 730

Milk Surveillance, *NCRH* 730

Food and Diet Surveillance 747

SECTION II. WATER 749

Gross Radioactivity in Surface Waters of the United States, June 1968, *FWPCA* 750

Radioactivity of Surface Waters of the Colorado River Basin, 1967 752

162

CONTENTS—continued

Page

SECTION III. AIR AND DEPOSITION 756

Radioactivity in Airborne Particulates and Precipitation 756
  1. Radiation Alert Network, August 1968, *PHS* 757
  2. Canadian Air and Precipitation Monitoring Program, August 1968 760
  3. Pan American Sampling Program, August 1968, *PAHO* and *PHS* 761
  4. Plutonium in Airborne Particulates and Precipitation, July–December 1967, *PHS* 761

SECTION IV. OTHER DATA 764

Radionuclides in Alaskan Caribou and Reindeer, March–May 1968, *PHS* 764

Environmental Levels of Radioactivity at Atomic Energy Commission Installations 766
  1. Atomics International, January–June 1968 766
  2. Paducah Plant, January–June 1968 769

Reported Nuclear Detonations, November 1968 771

ANNUAL SUBJECT INDEX, VOLUME 9 772

ANNUAL AUTHOR INDEX 778

Synopses iii

Guide for Authors Inside back cover

RADIOLOGICAL HEALTH DATA AND REPORTS

Published under the direction of

James G. Terrill, Jr., Director and
Dr. Raymond T. Moore, Deputy Director
National Center for Radiological Health

by the Standards and Intelligence Branch
Donald L. Snow, Chief

BOARD OF EDITORIAL ADVISORS

Dr. Harold O. Wyckoff
Department of Defense

Milton W. Lammering
Department of the Interior

Dr. Ronald G. Menzel
Department of Agriculture

Reuben Pomerantz
Department of Commerce

Robert E. Simpson
Food & Drug Administration, DHEW

John A. Harris
Atomic Energy Commission

STAFF

Managing Editor
Samuel Wieder

Assistant Managing Editor
Kurt L. Feldmann

Senior Technical Editor
Marvin Rosenstein

Technical Editors
Warren A. Brill
William H. Oates, Jr

Address correspondence to the Managing Editor, *Radiological Health Data and Reports*, National Center for Radiological Health, 12720 Twinbrook Parkway, Rockville, Md. 20852.

For subscriptions to *Radiological Health Data and Reports*, please use the order form on last page of this issue.

163

Reports

Cesium–137 Concentrations in Alaskans During the Spring of 1967

Henry J. L. Rechen, Richard L. Mikkelsen, O. Glen Briscoe, and *John F. Steiner, Jr.*[1]

During April and May 1967, cesium–137 concentrations were measured by the National Center for Radiological Health, Public Health Service, in 1,334 residents of 13 Alaskan villages and cities where caribou and reindeer are major sources of meat. Unshielded 7.5 x 7.5 cm NaI (Tl) scintillation detectors, held in the lap, were used for subjects of both sexes, from 4 to 91 years old, weighing 16 to 100 kilograms. The maximum cesium–137 concentrations ranged from 16.58 to 20.76 nCi/kg for males and from 12.92 to 18.21 nCi/kg for females.

Cesium–137 concentrations were highest in Ambler, Selawik, Noorvik, Shungnak and Anaktuvuk Pass, intermediate in Shishmaref, Noatak, Mekoryuk, Egegik and Teller, and lowest in three coastal cities where whaling is done (Wainwright, Point Hope and Barrow).

The Bureau of Indian Affairs (BIA) school lunch program, where used, did not appear to reduce significantly the cesium–137 concentrations in children. Average concentrations in men who were measured both years at Anaktuvuk Pass dropped 37.5 percent from 1966 to 1967; Selawik males showed a 15.7 percent decrease, while cesium–137 concentrations in adult male residents of Egegik increased 2 percent.

The "radiation dose index" defined in this report, for the highest individual value measured in 1967 was 0.17 rad/annum. The individual was an 82 kg man whose cesium–137 concentration was 21 nCi/kg. The guidance published by the Federal Radiation Council suggests that, while surveillance should be continued, no protective action appears to be necessary at this time.

Concentrations of radioactive cesium are regularly found in Alaskans whose major sources of foods include caribou and reindeer. The use of these animals for food is not confined to the Eskimo and Indian native populations. Because of the economy, availability of indigenous foods and diet preferences of the individuals, the highest reported rates of consumption occur in the inland native villages that have few other abundantly available foods for considerable periods of each year.

The National Center for Radiological Health (NCRH), Public Health Service (PHS) has periodically measured radioactive cesium in Alaskans to define the sizes and locations of the populations having significantly higher radiation doses to establish, if possible, year-to-year trends in the dose indices, and to provide a technical basis for calculating population dose indices for radioactive cesium for comparison with recommended radiation protection guides published by the Federal Radiation Council (*1*).

Studies of the radionuclide concentrations in arctic ecosystems in Alaska were begun in 1959 as a part of the Project Chariot Environmental Program (*2*). During the summer of 1962, a transportable whole-body counter (*3*) was used to examine 703 Eskimos and 78 non-native residents at Barrow, Point Hope, Kotzebue and Anaktuvuk Pass (*4*). Cesium–137 was the most important fallout radionuclide detected in the subjects examined. Similar reports have been published of measurements made in Canada, Norway, Sweden, Finland, and the Union of Soviet Socialist Republics (*5–9*).

---

[1] Mr. Rechen is deputy chief; Mr. Briscoe was electronics supervisor, Electronic Products Radiation Laboratory, National Center for Radiological Health; Mr. Steiner is with the Control Data Corporation, Washington Military Systems Division, Bethesda, Md. At the time of this study they were with the Environmental Surveillance and Control Program, NCRH, under whose auspices these studies are made. Mr. Mikkelsen was a radiation physicist, Department of Health and Welfare, State of Alaska, Anchorage, Alaska.

In 1962, Palmer and Perkins found cesium–134 in Alaskan Eskimos and in fallout (*10*). A similar finding for Swedish Lapps had been made by Liden and Andersson in March 1961 (*11*). The presence of detectable concentrations of cesium–134 in humans can be significant, particularly during times of reduced testing of nuclear devices in the atmosphere because it might indicate contamination of the human diet with recently-formed fallout. Cesium–134 has a physical half-life of 2.05 years as compared to the 30.76 year half-life of cesium–137.

After 1964, investigations have centered largely about three Alaskan native villages, Ambler, Anaktuvuk Pass, and Arctic Village (figure 1). Hanson had chosen the three inland villages for detailed study (*4*).

In the spring of 1965, whole-body measurements of 180 adult male patients and staff at 6 PHS Indian Health Hospitals in Alaska were made with an unshielded counter (*12*). Similar measurements were again made in the spring of 1966 at 7 Indian Health Hospitals, 2 other hospitals, and at three villages: Egegik, Anaktuvuk Pass, and Selawik (*13*). In all, 418 adult male subjects were measured, some of whom were local residents and not patients or staff at hospitals. Forty-nine men were counted both in 1965 and 1966, and there was reported to be an average decrease of 50 percent in whole-body cesium–137 content.

Cesium–137 body burdens in adults at Anaktuvuk Pass appear to have decreased since

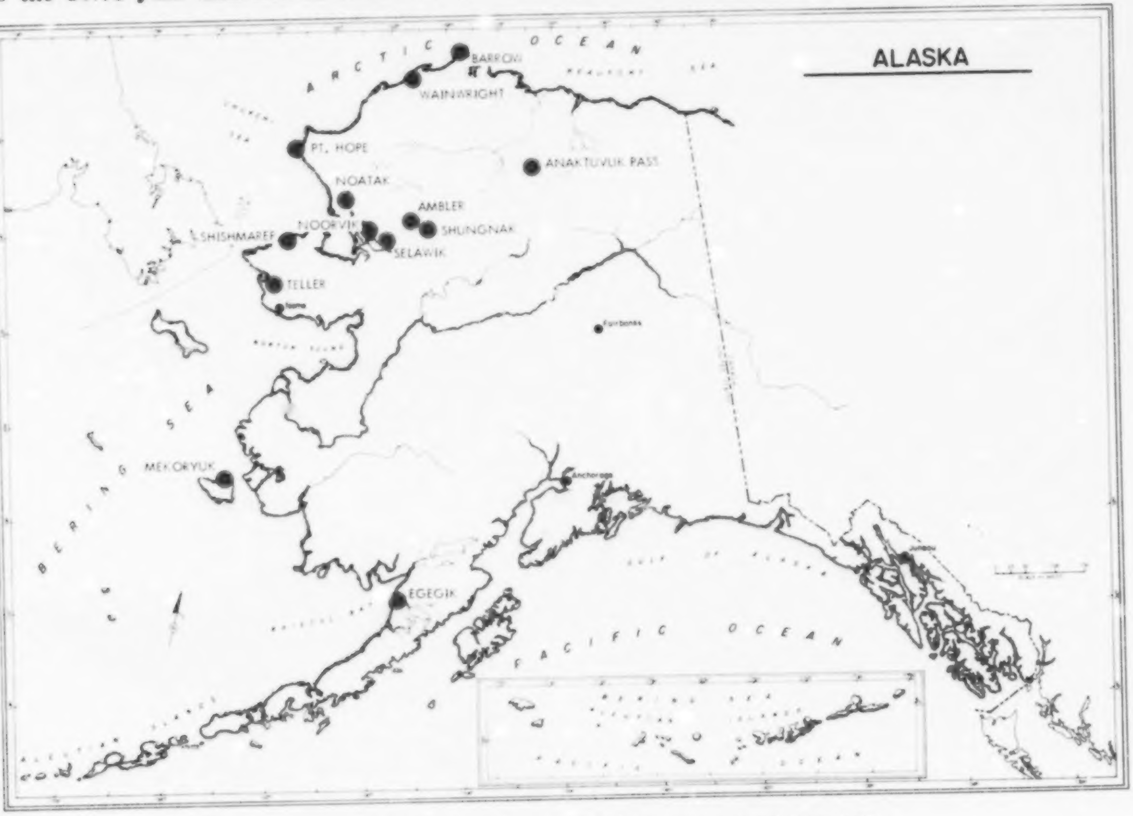

Figure 1. Alaska locations for whole body counting, April–May 1967

165

1964 (*14*), as have those of the higher coastal villages. Few data are available for the inland villages after 1964 (*15*), except for Hanson's reports on Ambler, Anaktuvuk Pass and Arctic Village. In 1966, the maximum values were found in residents of Selawik (*13, 16*). Because of the small numbers of individuals measured at any single place of residence, meaningful statistical conclusions have been difficult to make.

As a consequence the 1967 investigation by the NCRH was enlarged considerably in scope over those of 1965 and 1966. Counting locations were selected on the basis of community survey data furnished by the Alaska Department of Health and Welfare and by the Division of Indian Health, PHS, and included several villages in which large numbers of people ate appreciable quantities of caribou and reindeer. The object was to count as many people as possible at each location to establish a large statistical base for intervillage and time-sequential comparisons.

Measurements were made during mid-April to mid-May, at which time most of the village residents were still at home and had not yet departed for summer fishing or work areas. Many were about to make the transition from winter diets high in radiocesium (caribou and reindeer) to spring and summer diets (more abundant in fish, whales, and processed food) lower in radiocesium.

Plans were made to count subjects of both sexes and of all ages weighing over 15 kilograms who were capable of holding a detector and sitting quietly for 10 minutes.

Counting procedures

The technique of Palmer (*17*) was used with two detectors so that two subjects could be counted simultaneously. Both subjects, separated by about 4 meters, were comfortably seated, forearms on thighs, bent over unshielded 7.5 x 7.5 cm NaI(Tl) crystal and phototube detectors held on their laps with holders designed to keep the thighs together. Ten-minute counts were taken using 200 channels for each spectrum at 10 keV per channel in a multichannel pulse-height analyzer. Punched paper tapes of each spectrum were made. Duplicate tapes were mailed to the laboratory at NCRH for computer analysis.

Field estimates of cesium–137 content (nCi) were made for each pair of subjects immediately after counting and the results were given to the subjects at their request. The full spectra were examined and the subject recounted if the spectra appeared abnormal. Anomalies might easily result from power supply variations, gamma radiation from radium-painted watches, compasses and jewelry or from damage to the detectors. Occasional unshielded backgrounds without subjects were taken as were operational backgrounds using team members as phantoms. The cesium–137 content of two of the team members, 3 and 7 nCi, had previously been measured in the whole-body counter at the U.S. Naval Medical Center in Bethesda, Md. The average of the backgrounds for the two team members in each location was subtracted from the gross counts of the other subjects and 5 nCi were added to the subjects' values to correct for the subtractive step. Tests at NCRH with different weight human subjects had shown that the amount of background to be subtracted from each count was essentially constant and was, within statistical limits, independent of the sex and weight of the subject. The background that was subtracted included the contribution of potassium–40, both from the subject's body and from his surroundings, to the cesium–137 spectral region.

In scintillation counting, cesium–137 has its useful gamma photopeak at 0.662 MeV (*18*). The cesium–137 content (nCi/kg) of the subject was obtained by:

(1) adding the spectral areas, in counts, believed to represent 0.59 to 0.73 MeV;

(2) subtracting background;

(3) dividing by the counting time to give net counts per minute (CPM);

(4) multiplying CPM by the counter calibration factor (nCi/CPM);

(5) adding 5 nCi, to correct for the subtraction of the unavoidable cesium–137 content of the human "background phantom";

(6) dividing the body content (nCi) by the subject's weight (kg).

Table 1. Physical characteristics of calibration phantoms, 1967

Type		Dimensions			Radioactivity content				Detector calibration factors for cesium-137					
					Cesium-137		K-natural		Crystal No. 1		Crystal No. 2		Average of 1 and 2	
No.	Composition	Weight (kg)	Height (meters)	$\frac{(Wt.)}{(ht.^3)}$ (kg/m³)	(nCi)	(nCi/kg)	(g)	(g/kg)	$\left(\frac{nCi}{CPM}\right)$	$\left(\frac{nCi}{kg\text{-}CPM}\right)$	$\left(\frac{nCi}{CPM}\right)$	$\left(\frac{nCi}{kg\text{-}CPM}\right)$	$\left(\frac{nCi}{CPM}\right)$	$\left(\frac{nCi}{kg\text{-}CPM}\right)$
1	Water:.......	17.25	1.020	16.3	0.00	0.00	32.68	1.90						
2		17.25	1.020	16.3	157.50	9.14	32.68	1.90	0.0853	0.00495	0.0921	0.00523	0.08776	0.00509
3		33.70	1.275	16.3	.00	.00	66.12	1.96						
4		33.70	1.275	16.3	314.06	9.32	66.12	1.96	.1377	.00408	.1433	.00425	.1405	.00417
5	Sugar:.......	63.60	1.65	14.2	.00	.00	....	....						
6		63.60	1.65	14.2	156.5	2.46	....	....	.2398	.00377	.2310	.00363	.2354	.00370
7		63.60	1.65	14.2	1,939	30.45	....	....	.2292	.00360	.2385	.00375	.2339	.00368
8		72.75	1.72	14.3	.00	.00	....	....						
9		72.75	1.72	14.3	180.4	2.48	....	....	.2606	.00358	.2527	.00347	.2567	.00353
10		72.75	1.72	14.3	2,215	30.45	....	....	.2363	.00323	.2223	.00305	.2339	.00315
11		81.80	1.80	14.0	.00	.00	....	....						
12		81.80	1.80	14.0	204.2	2.50	....	....	.2696	.00330	.2428	.00297	.2562	.00314
13		81.80	1.80	14.0	2,408	29.45	....	....	.2465	.00301	.2557	.00312	.2511	.00307

During computer analysis, a search was made for the highest 3-channel sum over a range of 4 channels, to find the cesium–137 gamma-ray peak in the spectrum and to locate the 15 channel portion of the spectrum to be summed. One out of each 10 spectra was plotted and examined for evidence of cesium–134 at 0.80 MeV (*19*). All results reported are derived from the computer analysis although field estimates were usually within 10 percent. Potassium–40 cannot be measured by this technique because the subject's body substitutes approximately as many gamma-ray counts in the potassium spectral region (*20*) as it removes from background by shielding.

No data are available to allow assignment of statements of overall statistical accuracy to the values reported for the cesium–137 determinations except for counting statistics because cross-calibration has not been done with human subjects having accurately known cesium contents in the ranges studied.

Calibration

The detectors were calibrated at the NCRH laboratory with thirteen water or sugar phantoms of five different weights, each arranged in the field counting position. Five of the phantoms did not contain cesium–137 and were used to measure background, duplicating in form those that contained cesium–137.

The water phantoms were contained in one liter or fractional liter thin-plastic bottles, cubical and cylindrical in shape. Measured amounts of potassium chloride (KCl), stable cesium chloride (CsCl), and radioactive CsCl from an Amersham standard were dissolved in deionized, distilled water. The accuracy and spectral purity of the cesium–137 and potassium–40 contents were checked by measurements of aliquots with a large shielded NaI scintillation counter and a 200-channel pulse height analyzer. The cesium–137 standard, in comparison with previous laboratory calibrations was within 5 percent of the expected value.

The sugar phantoms were assembled from 2-pound paper bags of commercial granulated sugar, having identical cesium–137 sources taped to each bag. Measurements were made with the source side of each bag facing toward and away from the detectors and the results were averaged.

A smooth function was fitted to the average calibration factors listed in table 1, and was found to be:

$$\frac{nCi}{CPM} = 0.012\ (W)^{0.7} \qquad 1967\ (1)$$

$$\frac{nCi}{kg\text{-}CPM} = \frac{0.012}{(W)^{0.3}} \qquad 1967\ (2)$$

where nCi = total cesium-137 in phantom, nanocuries;

$\frac{nCi}{kg}$ = concentration of cesium-137 in phantom, nCi/kg;

CPM = sum of net counts per minute in channels corresponding to gamma energy from 0.59 through 0.73 MeV;

W = weight of phantom, in kilograms.

Equations (1) and (2) were used to calculate the cesium-137 body contents and concentrations of all Alaskans counted during April and May 1967.

The data obtained in April and May 1966 (the basis for reference *13*) were recalculated using a similar function for the slightly less sensitive detector that was used. Equations (3) and (4) were derived for recalculation of the 1966 data:

$$\frac{\text{nCi}}{\text{CPM}} = 0.0134\ (\text{W})^{0.8} \qquad 1966\ (3)$$

$$\frac{\text{nCi}}{\text{kg-CPM}} = \frac{0.0134}{(\text{W})^{0.2}} \qquad 1966\ (4)$$

The use of similar equations is possible because the detector used in 1966 was physically the same as those used in 1967 except for a slight difference in housing and in resolution.

The average for the two 1967 detectors was used in developing equations (1) and (2).

Of the 1,334 subjects whose cesium-137 concentrations were measured, only 55 had net counting rates (CPM) in the 95-percent confidence interval, that were measured with a precision less than ± 10 percent because of random counting statistics. Of the 55 cases, 38 had a precision of estimate between ± 10 and ± 30 percent, 10 between ± 30 and ± 100 percent, and 7 were indistinguishable from zero (*21*).

Because counting statistics were not a major factor in the precision of the averaged results, they were not included in subsequent tabulations.

Interviews

Each subject was interviewed just before counting, and height (± 1 cm) and weight (± 1 kg) were measured.

Diet pattern interviews were made but did not give data sufficient to place any absolute value on the subject's cesium content, even within wide ranges. The results of the diet statements are not analyzed in this report.

Approximate village census data, provided by the BIA school or the village councils, were used to estimate the degree to which we were able to sample each population group. Participation was entirely voluntary.

Classification of data

For purposes of averaging individual results, the resident population counted in each village was divided into six groups by sex and weight. Weight groups were: 16–45 kg, 46–65 kg and >65 kg.

Weight groups, rather than age groups, were chosen because the formula used for calculating average radiation dose requires that average body weight but not age, be known. Age becomes a factor when genetically significant dose estimates are attempted. The latter calculations require detailed knowledge of fertility and of the sizes of the population groups interacting to form genetic "pools". The present study was designed to collect preliminary information that might be used to judge the need for more detailed studies and their scope. A second reason for using weight groups was to obtain a smooth distribution of data for intervillage comparisons. In many of the villages, key age groups are missing because of attendance at high school, mortality during epidemics, and other factors such as emigration or perhaps unusual birth ratios of the sexes.

With the two exceptions (reporting by weight group rather than by age, and not being able to measure potassium concentrations), Miettinen's criteria for reporting intercomparable data are met (*22*).

Results of counting

Figure 1 shows the 13 locations at which whole body counting for radiocesium was performed on 698 male and 636 female subjects from mid-April to mid-May 1967. Except for only two persons, the counting locations were also the residences of all of the subjects. The estimated total population of the 13 villages and cities was 2,633 male and 2,395 female. Barrow, where only 47 persons were counted, was estimated to have 1,800 residents.

Table 2 contains the average and maximum concentrations of cesium-137 measured in 1967. No spectrum examined showed evidence of cesium-134. Table 3 contains the similar data obtained by Fitzpatrick in April–May 1966,

Table 2. Average and maximum concentrations of cesium-137 in Alaskans by place of residence, 1967

Location and date (1967)	Sex and approximate population [a]	Weight range (kg)	Number counted	Average height [b] (cm)	Average weight [b] (kg)	Average year born	Cesium-137 concentrations		Ratio: maximum to average
							Average (nCi/kg)	Maximum (nCi/kg)	
Ambler 4/22-23	Male 69	16-45	19	132	29	1958	8.39	13.99	
		46-65	9	168	58	1944	9.97	16.84	
		>65	13	172	77	1925	10.97	20.76	
	Female 72	16-45	17	131	30	1957	8.10	13.80	
		46-65	20	158	57	1937	9.09	17.47	
		>65	8	162	72	1928	4.88	7.28	
Anaktuvuk Pass 5/3	Male 65	16-45	4	138	34	1956	3.92	5.52	
		46-65	9	138	60	1938	8.86	18.49	
		>65	14	168	72	1921	8.38	17.16	
	Female 60	16-45	4	141	37	1951	5.70	9.42	
		46-65	13	155	55	1925	5.90	10.08	
		>65	2	160	73	1936	4.88	5.25	
Barrow 5/4	Male 900	16-45	13	134	32	1957	.33	.88	
		46-65	9	164	55	1950	.65	1.00	
		>65	2	179	85	1938	1.01	1.31	
	Female 900	16-45	10	130	30	1958	.41	.75	
		46-65	11	154	52	1951	.57	1.57	
		>65	2	159	67	1923	.79	.94	
Egegik 5/14-15	Male 91	16-45	25	133	31	1956	2.25	7.11	
		46-65	18	163	57	1938	4.21	14.05	
		>65	14	170	79	1925	2.80	7.18	
	Female 87	16-45	15	129	28	1958	3.16	6.84	
		46-65	14	156	54	1940	2.26	8.13	
		>65	4	152	74	1929	4.24	6.57	
Mekoryuk, Nunivak Island 5/16-17	Male 171	16-45	13	131	32	1956	2.45	4.02	
		46-65	16	161	58	1938	4.61	6.23	
		>65	16	169	72	1927	4.65	7.71	
	Female 133	16-45	11	132	34	1950	2.66	6.01	
		46-65	22	151	57	1943	2.88	4.82	
		>65	8	154	75	1925	2.14	3.30	
Noatak 4/18-19	Male 105	16-45	24	134	31	1958	2.67	5.93	
		46-65	13	164	59	1938	4.12	8.00	
		>65	34	172	75	1926	5.97	9.33	
	Female 86	16-45	24	134	32	1958	2.31	5.00	
		46-65	23	156	56	1940	3.55	5.87	
		>65	15	160	77	1919	2.62	4.41	
Noorvik 4/20-21	Male 252	16-45	23	140	35	1954	5.50	8.20	
		46-65	22	163	55	1942	8.50	18.08	
		>65	35	170	73	1925	10.90	19.90	
	Female 214	16-45	10	139	35	1956	6.03	9.74	
		46-65	37	157	57	1935	6.88	14.56	
		>65	15	156	75	1917	4.34	10.42	
Point Hope 5/8-9	Male 190	16-45	12	137	34	1957	.79	1.74	
		46-65	14	165	60	1937	1.48	2.88	
		>65	15	172	76	1927	1.07	1.77	
	Female 162	16-45	11	139	36	1953	.60	1.17	
		46-65	14	157	56	1939	.84	1.56	
		>65	12	158	73	1924	.73	1.50	
Selawik 4/25-26	Male 225	16-45	33	132	30	1957	8.04	16.58	
		46-65	19	166	59	1929	11.39	19.30	
		>65	15	171	76	1922	9.71	17.28	
	Female 216	16-45	45	130	28	1957	7.85	15.62	
		46-65	10	155	55	1925	8.87	18.21	
		>65	14	158	78	1927	7.47	12.92	
Shishmaref 4/28-29	Male 132	16-45	22	132	30	1958	3.50	7.02	
		46-65	15	163	59	1940	4.81	10.91	
		>65	25	168	77	1926	4.63	11.46	
	Female 125	16-45	22	132	30	1957	3.52	6.71	
		46-65	28	154	54	1942	3.22	6.10	
		>65	10	158	77	1932	3.17	4.43	
Shungnak [illegible]	Male 93	16-45	29	131	29	1957	6.25	10.84	
		46-65	14	165	56	1934	8.53	13.15	
		>65	13	175	74	1925	12.02	17.93	
	Female 82	16-45	22	130	28	1955	6.39	10.74	
		46-65	23	157	55	1928	6.56	12.40	
		>65	3	163	72	1912	4.29	5.87	
[illegible]	Male 166	16-45	14	135	32	1957	2.08	3.93	
		46-65	15	164	60	1934	3.83	6.24	
		>65	9	169	75	1930	3.92	7.00	
	Female 125	16-45	19	135	33	1955	1.77	4.37	
		46-65	18	157	56	1936	2.27	6.16	
		>65	6	155	74	1923	1.58	3.38	
Wainwright [illegible]	Male 170	16-45	21	137	35	1954	1.76	3.03	
		46-65	23	163	58	1935	3.11	6.97	
		>65	45	171	73	1925	3.71	7.09	
	Female 143	16-45	21	136	34	1955	1.89	4.43	
		46-65	22	154	56	1935	1.91	4.63	
		>65	21	162	79	1928	1.48	2.63	
Total 4/18-5/17	Male 2,633	16-45	252	134	32	1956	4.20	16.58	3.95
		46-65	196	164	58	1938	5.72	19.30	3.37
		>65	250	171	76	1926	6.38	20.76	3.26
	Female 2,395	16-45	231	133	32	1955	4.35	15.62	3.59
		46-65	285	156	55	1937	4.87	18.21	3.74
		>65	120	158	74	1925	3.22	12.92	4.01

---

[a] Taken from approximate winter census prepared by B.I.A. school or village council.
[b] In 1967, heights and weights were measured. In 1966, the individuals were asked their approximate height and weight.

Table 3. Average and maximum concentrations of cesium-137 in Alaskan males by place of residence, 1966

Residence	Weight range (kg)	Number counted	Average height ᵃ (cm)	Average weight ᵃ (kg)	Average year born	Cesium-137 concentrations		Ratio: maximum to average
						Average (nCi/kg)	Maximum (nCi/kg)	
Akutan	46–65	1	165	65	1925	0.13	0.13	
Alakanuk	46–65	1	165	54	1937	.10	.10	
Anaktuvuk Pass	46–65	3	161	59	1936	9.62	16.81	
	>65	5	169	74	1917	10.29	13.17	
Anchorage	46–65	10	166	59	1934	.34	1.09	
	>65	43	173	76	1932	.36	2.16	
Angoon	>65	1	173	78	1902	.64	.64	
Aniak	>65	1	157	68	1947	.52	.52	
Anvik	>65	1	180	79	1929	.63	.63	
Barrow	46–65	6	168	63	1939	2.25	3.79	
	>65	40	171	75	1927	2.21	5.99	
Bethel	46–65	12	162	61	1929	1.03	3.33	
	>65	20	172	75	1926	.60	2.10	
Chefornak	>65	2	169	69	1941	.25	.26	
Chignik	46–65	3	160	61	1924	1.00	1.10	
Dillingham	46–65	7	165	60	1930	1.22	5.56	
	>65	16	175	75	1933	1.63	11.81	
Douglas	>65	5	174	79	1933	.08	.14	
Eagle River	>65	1	173	70	1897	.03	.03	
Eek	>65	1	173	70	1909	.63	.63	
Egegik	46–65	12	166	59	1925	5.22	13.49	
	>65	19	171	77	1923	2.71	8.02	
Elim	>65	1	173	68	1942	1.30	1.30	
Emmonak	>65	1	183	75	1941	.09	.09	
Fairbanks	46–65	2	168	58	1936	.18	.32	
	>65	27	177	82	1933	.30	2.43	
Fort Yukon	>65	1	173	77	1908	.21	.21	
Gakona	>65	1	175	82	1933	.63	.63	
Goodnews Bay	46–65	1	160	59	1930	.12	.12	
Hoonah	>65	1	173	68	1901	.00	.00	
Iliamna	46–65	1	168	55	1901	2.38	2.38	
Juneau	16–45	1	173	44	1953	.05	.05	
	46–65	3	169	58	1934	.03	.04	
	>65	22	177	80	1934	.08	.17	
Kake	>65	2	169	78	1915	.78	1.07	
Kiana	>65	1	168	67	1939	5.25	5.25	
Kivalina	>65	1	165	79	1930	2.53	2.53	
Klawock	>65	1	170	75	1902	.49	.49	
Kodiak	46–65	1	163	64	1904	.21	.21	
	>65	1	173	82	1940	.02	.02	
Kotzebue	46–65	5	166	63	1930	3.69	7.14	
	>65	15	175	77	1924	3.23	9.69	
Kwethluk	46–65	1	152	52	1950	.25	.25	
	>65	1	160	70	1937	.42	.42	
Kwigillingok	46–65	1	160	64	1914	1.24	1.24	
Manokotak	46–65	2	167	64	1931	1.23	1.50	
Metlakatla	46–65	2	169	58	1935	.29	.35	
Naknek	>65	1	163	66	1910	8.23	8.23	
Nome	>65	1	173	70	1931	.45	.45	
Noorvik	46–65	1	163	64	1904	6.42	6.42	
Petersburg	46–65	1	173	50	1899	.38	.38	
Platinum	46–65	1	168	57	1942	.13	.13	
Point Hope	46–65	1	157	46	1952	.58	.58	
Selawik	46–65	11	166	61	1926	17.56	24.37	
	>65	22	171	73	1923	17.48	31.91	
Shishmaref	>65	1	170	77	1918	6.28	6.28	
Sitka	46–65	10	170	60	1928	.23	.76	
	>65	23	174	79	1932	.27	.62	
Sleetmute	46–65	1	160	53	1895	.14	.14	
Tanana	46–65	14	167	61	1920	.53	2.56	
	>65	16	171	74	1926	.39	1.64	
Tatitlek	>65	1	173	67	1894	.20	.20	
Unalakleet	46–65	1	173	59	1945	1.30	1.30	
	>65	1	173	66	1942	.83	.83	
Wainwright	>65	1	165	84	1918	2.25	2.25	
Wales	>65	1	173	96	1920	1.56	1.56	
Wrangell	>65	1	175	86	1924	.14	.14	
Yakutat	46–65	1	163	59	1924	.04	.04	
Total (April–May 1966)	16–45	1	173	44	1953	0.05	0.05	1.00
	46–65	116	165	60	1928	3.19	24.37	7.64
	>65	300	173	77	1928	2.45	31.91	13.02

ᵃ In 1966, the individuals were asked their approximate heights and weights.

recalculated as explained.

Table 4 is a comparison of 1967 with 1966 values for the 8 villages having residents counted both years. Table 5 is a comparison of 1967 with 1966 values for the 38 men, residing at 5 villages, who were counted both years. All except 2 lived at Anaktuvuk Pass, Egegik, or Selawik. The difficulty of obtaining the same subjects, year after year is demonstrated by the fact that in 1967, 25 men left Selawik for employment at a coastal cannery just a few days before the counting team arrived.

Table 4. Comparison of 1967 to 1966 average and maximum cesium-137 concentrations in Alaskan males by place of residence

Residence	Weight range (kg)	Number counted and year	Average height [a] (cm)	Average weight [a] (kg)	Average year born	Cesium-137 concentrations		Ratio of 1967 to 1966	
						Average (nCi/kg)	Maximum (nCi/kg)	Average	Maximum
Anaktuvuk Pass	46-65	3—1966	161	59	1936	9.62	16.81		
		9—1967	168	60	1938	8.86	18.49	0.92	1.10
	>65	5—1966	169	74	1917	10.29	13.17		
		14—1967	168	72	1921	8.38	17.16	.82	1.30
Barrow	46-65	6—1966	168	63	1939	2.25	3.79		
		9—1967	164	55	1950	.65	1.00	.29	.26
	>65	40—1966	171	75	1927	2.21	5.99		
		2—1967	179	85	1938	1.01	1.31	.46	.22
Egegik	46-65	12—1966	166	59	1925	5.22	13.49		
		18—1967	163	57	1938	4.21	14.05	.81	1.04
	>65	19—1966	171	77	1923	2.71	8.02		
		14—1967	170	79	1925	2.80	7.18	1.03	.90
Noorvik	46-65	1—1966	163	64	1904	6.42	6.42		
		22—1967	163	55	1942	8.50	18.08	1.32	2.82
Point Hope	46-65	1—1966	157	46	1952	.58	.58		
		14—1967	165	60	1937	1.48	2.88	2.55	4.97
Selawik	46-65	11—1966	166	61	1926	17.56	24.37		
		19—1967	166	59	1929	11.39	19.30	.65	.79
	>65	22—1966	171	73	1923	17.48	31.91		
		15—1967	171	76	1922	9.71	17.28	.56	.54
Shishmaref	>65	1—1966	170	77	1918	6.28	6.28		
		25—1967	168	77	1926	4.63	11.46	.74	1.82
Wainwright	>65	1—1966	165	84	1918	2.25	2.25		
		45—1967	171	73	1925	3.71	7.09	1.65	3.15
Total	46-65	34—1966	166	60	1928	8.97	24.37		
		91—1967	165	57	1938	6.32	19.30	0.71	0.79
	>65	88—1966	171	75	1926	6.64	31.91		
		115—1967	170	75	1924	5.15	17.28	0.78	0.54

[a] In 1967, the heights and weights were measured. In 1966, the individuals were asked their approximate height and weight.

The comparisons of values given in tables 3, 4 and 5 are most meaningful for the three villages of Anaktuvuk Pass, Egegik and Selawik. Many of the 1966 subjects who were residents of other villages were hospital patients or employees, eating non-native diets for indefinite periods of time away from home. Thirty-nine of 52 reported places of residence, in 1966, were represented by only 1 or 2 subjects each.

Table 5. Comparison of 1967 to 1966 average and maximum cesium-137 concentrations in Alaskan men who were counted in both years

Residence	Weight range (kg)	Number counted and year	Average [a] height (cm)	Average [a] weight (kg)	Average year born	Cesium-137 concentrations		Ratio of 1967 to 1966	
						Average (nCi/kg)	Maximum (nCi/kg)	Average	Maximum
Anaktuvuk Pass	46-65	2—1966	163	57	1937	12.09	16.81		
		1967	162	56		6.60	7.06	0.55	0.42
	>65	5—1966	169	74	1924	10.29	13.17		
		1967	168	72		6.81	10.18	.66	.77
Egegik	46-65	9—1966	165	60	1921	5.66	13.49		
		1967	160	57		6.00	14.05	1.06	1.04
	>65	9—1966	173	77	1924	3.33	8.02		
		1967	169	79		3.17	7.18	.95	.89
Selawik	46-65	3—1966	175	63	1920	16.86	20.33		
		1967	170	61		14.25	16.15	.85	.79
	>65	8—1966	171	73	1928	11.84	17.30		
		1967	172	75		9.98	14.49	.84	.84
Noorvik	46-65	1—1966	163	64	1904	6.42			
		1967	160	52		9.68		1.51	
Point Hope	46-65	1—1966	157	46	1952	.58			
		1967	168	54		.42		.72	
Total	46-65	16—1966	166	60	1922	8.30	20.33		
		1967	163	57		7.50	16.15	0.90	0.79
	>65	22—1966	171	75	1923	8.02	17.30		
		1967	169	76		6.48	14.49	0.81	0.84

[a] In 1967, the heights and weights were measured. In 1966, the individuals were asked their approximate height and weight.

Interpretation of 1967 results

The summary at the end of table 2 gives the average cesium–137 concentrations, by sex and weight group, for all persons counted in April and May 1967. Five villages and cities, (Ambler, Selawik, Noorvik, Shungnak and Anaktuvuk Pass) had averages about 1½ to 2 times the overall average concentrations. These were estimated to contain 27 percent of the total population of the 13 locations where counting was done. The five communities are inland river villages and depend on hunting for meat (particularly caribou and moose), with practically all fishing being done in the summer and fall.

Five other villages, Shishmaref, Noatak, Mekoryuk, Egegik, and Teller, contain about 24 percent of the total population of the 13 locations where counting was done in 1967. The average concentrations for individuals in these communities ranked slightly below the overall averages. These communities have free access to hunting or commercial sources of reindeer or caribou. However, with the exception of Noatak, they are located on or near the coast where river and estuarial fishing is practiced much of the year, where salmon may be abundant, and where sealing and walrus hunting may provide additional sources of food or income. At Mekoryuk, each head of a family may kill five reindeer annually free of charge. Egegik is a village oriented around salmon fishing and canning. Only at Egegik and Noatak can the caribou be freely hunted when they are available. Here, too, moose are an important diet element when in season, and the meat may furnish part of the cesium–137 in the total diet of some residents.

The remaining 49 percent of the population in the 13 communities are in Wainwright, Point Hope, and Barrow, three cities having the lowest average concentrations of cesium–137. The residents of these cities concentrate on whaling, sealing, and other coastal hunting in the winter. Coastal, estuarial, and river fish and birds are abundant. While caribou might be hunted directly, residents also purchased the meat in the local stores.

A fourth class of communities, shown by the 1966 data in table 3, are those in which almost no native Alaskan foods are consumed. Without exception, the average concentrations of cesium–137 in these communities seemed to be almost as low as in the remainder of the United States. These communities were not included in the 1967 sample.

The highest individual concentrations of cesium–137 were found in Selawik and Ambler, in both men and women. The highest individual body content was 1,700 nCi, in a 38 year old, 82 kg male resident of Ambler. The cesium–137 concentration was 20.76 nCi/kg.

In general, the sexes were indistinguishable in the 16–45 kg weight class, by average height, weight and age as well as by average and maximum cesium–137 concentrations. In the men, the average factors above increased slightly with increasing weight class.

In the 46–65 kg and >65 kg weight classes, the women were almost the same average age as the men although they were shorter and lighter in average weight. Average and maximum cesium concentrations in women reached a peak in the 46–65 kg weight class, lower than that for the men, and dropped for those over 65 kg in weight.

In each village the maximum individual cesium–137 concentration was usually about two times the average for each weight class, except for men >65 kg where it was 1.8 times, and for women >65 kg where it was 1.6 times. The expected minimum appears generally to be the same factor below the average as the maximum is above it except in those villages where a resident (such as a school teacher) does not eat local food and has a body concentration of cesium–137 only slightly above zero.

Determination of the effect of school lunch programs

Of the 13 communities studied in 1967, nine had schools operated by the Bureau of Indian Affairs, U.S. Department of the Interior. These 9 schools, gave each child a full meal for every noon lunch, 5 days a week, consisting of processed food, a diet presumably lower in radiocesium than the local food. The other 4 schools at Ambler, Anaktuvuk Pass, Egegik and Teller, were operated by the Department of Education, State of Alaska, and did not give noon lunches.

A comparison of data listed in table 7 was made to see if the supplementary food seemed to reduce cesium concentrations in the children relative to the adults in BIA villages. No significant overall difference was evident, perhaps because the school lunches provided only a small fraction of each child's total daily intake of food, or because the lunches of the BIA school children were not significantly different in cesium content from those of the others.

Table 6. Comparison of effect of 1967 BIA and State school diets on cesium-137 concentrations in children relative to adults

Type of school and location	Ratio of average cesium-137 concentration $\frac{16\text{–}45\text{ kg}}{46\text{–}65\text{ kg}}$	
	Male	Female
State school:		
Ambler	0.84	0.89
Anaktuvuk Pass	.44	.97
Egegik	.53	1.40
Teller	.54	.78
State school average ratio	0.59	1.03
BIA school:		
Barrow	0.69	0.81
Mekoryuk	.53	.92
Noatak	.65	.65
Noorvik	.65	.88
Point Hope	.53	.71
Selawik	.73	.87
Shishmaref	.73	1.09
Shungnak	.73	.97
Wainwright	.57	.99
BIA school average ratio	0.65	0.88

Comparison of 1967 with 1966 results

In the 8 communities listed in table 4, where 122 male residents had been counted in 1966 and 204 in 1967, there had been a 25 percent reduction over the past year in average cesium-137 concentrations. The individual maxima decreased approximately 33 percent.

Table 5 compares the data for 38 men residents in 5 communities who were counted both years. The overall decrease in average cesium-137 concentration was 15 percent. Each of the three principal villages counted showed a different pattern; the average concentration in men at Anaktuvuk Pass dropped by 37.5 percent; Selawik showed a 15.7 percent decrease, while the residents of Egegik showed an insignificant 2 percent increase. The maximum individual concentrations changed comparably.

Radiation dose indices

The average annual radiation dose in an Alaskan from an average concentration of cesium-137 of one nanocurie per kilogram of body weight may be estimated as:

$$r = (W^{0.3} + 4.5)\ \text{mrad/annum per nCi/kg} \quad (5)$$

where W = body weight in kg, from 15 to 100 kg.

Equation (5) was derived from the dose calculations made by Miettinen (*8*) assuming that cesium-137 emitted 0.85 gamma photons per disintegration (*23*). The contribution from beta particles and conversion electrons of cesium-137 in equation (5) is 4.5 mrad/a per nCi/kg. The term, $W^{0.3}$ mrad/a, empirically describes the dose from the absorption of gamma and X rays and closely parallels the inverse of equation (2), the gamma-ray counter sensitivity. The method of dose calculation incorporates an allowance for average subject heights associated with the corresponding average weights.

"Radiation dose index", r_i, may be defined as the product of r and $A_{s,w}$;

$$r_i = rA_{s,w} = (W^{0.3} + 4.5)A_{s,w} \quad (6)$$

Where r_i = "radiation dose index" for a specific sex-weight group in a community at a specific time, in mrad/a;
r = average annual radiation dose from an average concentration of one nCi/kg, in mrad/a per nCi/kg;
$A_{s,w}$ = average cesium-137 concentration in a specific sex-weight group in a community at a spcific time, in nCi/kg.

The "radiation dose index" applies only to the date of measurement of one sex-weight group in a given community. In the absence of any other data or guides, the radiation dose index may be assumed to be equal to the average annual radiation dose from cesium-137 for individuals in the particular community group being considered. If other data are available to permit calculation of other radiation dose indices for the same or a comparable group, or for individuals from that group, the average annual radiation dose will be the sum of the radiation dose indices, each multiplied by the fraction of the year during which the index was believed to apply. In this way, approximate allowances may be made in calculating annual population doses, for example, for groups of patients, students, or workers who change residences periodically.

For each of the 13 communities surveyed in April–May 1967, radiation dose indices have been calculated from table 2 and table 3, using equation (6) for each of the six sex-weight classifications. The indices are listed in table 7. If more than 2 individuals from a community group were surveyed in 1966, the data for that year are also given in table 7.

Table 7. Radiation dose indices for cesium-137 in Alaskan communities,[a] April–May 1966 and 1967

Location	Date		Male			Female		
	Month	Year	16–45 kg	46–65 kg	>65 kg	16–45 kg	46–65 kg	>65 kg
Measured in 1966 and 1967:								
Anaktuvuk Pass	5	1966	-----	76	84	-----	-----	-----
	5	1967	29	70	69	42	46	40
Barrow	5	1966	-----	18	18	-----	-----	-----
	5	1967	2	5	8	3	5	6
Egegik	5	1966	-----	41	22	-----	-----	-----
	5	1967	17	33	23	23	18	35
Selawik	5	1966	-----	138	143	-----	-----	-----
	4	1967	59	90	79	58	70	61
Measured only in 1967:								
Ambler	4	1967	62	79	90	59	71	40
Mekoryuk	5	1967	18	36	38	20	23	17
Noatak	4	1967	20	33	49	17	28	22
Noorvik	4	1967	40	67	89	44	54	35
Point Hope	5	1967	6	12	9	4	7	6
Shishmaref	4	1967	26	38	38	26	25	26
Shungnak	4	1967	46	67	98	47	51	35
Teller	5	1967	15	30	32	13	18	13
Wainwright	5	1967	13	25	30	14	15	12
Measured only in 1966:								
Anchorage	4	1966	-----	3	3			
Bethel	5	1966	-----	8	5			
Chignik	5	1966	-----	8	-----			
Dillingham	5	1966	-----	10	13			
Douglas	5	1966	-----	-----	< 1			
Fairbanks	5	1966	-----	1	3			
Juneau	5	1966	< 1	< 1	< 1			
Kotzebue	5	1966	-----	29	26			
Sitka	4	1966	-----	2	2			
Tanana	5	1966	-----	4	3			

[a] Values of r_i, in mrad/a, by year, sex, and weight group.

In the calculations, the following values of r were used:

Sex	Average 1967 weight (kg)	r (mrad/a per nCi/kg)
Male:	32	7.33
	58	7.88
	76	8.17
Female:	32	7.33
	55	7.83
	74	8.14

Omitted from table 7 for lack of data are the indices for at least 163 men and 97 women reported to be temporarily away from their communities of residence in 1967 (hospital patients, teenagers at boarding school, etc).

An important conclusion may be drawn from equations (2) and (6). Equation (2) states, in slightly modified form:

$$A_{s,w} = CPM/(83.3W^{0.3}), \text{ in nCi/kg}$$

and equation (6) states:

$$r_i = (W^{0.3} + 4.5)A_{s,w}, \text{ in mrad/a.}$$

If the two equations are combined, we find that

$$r_i = (CPM)(W^{0.3} + 4.5)/(83.3W^{0.3})$$

and, therefore,

$$r_i = (CPM)(0.012 + 0.054/W^{0.3}) \qquad (7)$$

where, as defined before,

r_i = radiation dose index for a specific sex-weight group, in mrad/a,

CPM = sum of net counts per minute in channels corresponding to gamma-ray energy from 0.59 through 0.73 MeV,

W = weight of subject, in kg.

For W = 16 kg, the weight of a 4 or 5-year-old child,

$$r_i = 0.0355(CPM) \qquad (8)$$

For W = 100 kg, the weight of the largest subject observed in this study,

$$r_i = 0.0256(CPM) \qquad (9)$$

If the average of the two coefficients of equations (8) and (9) is taken and rounded off (corresponding to a subject weight of 36 kg), an estimate of the "radiation dose index" may be made for all subjects from a single formula,

$$r_i = 0.03(CPM) \qquad (10)$$

The error, for subjects from 16 to 100 kg, will not exceed 17 percent and will be negligible if a well distributed sample of subjects of all sizes is taken.

Equations (8), (9) and (10) show that the average radiation dose to a person from corporeal cesium-137, as measured by a 7.5 x 7.5 cm NaI(Tl) scintillation crystal held in the lap and covered by the forearms and upper body, is almost entirely a function of the cesium-137 concentration in the body, not of the total body content of cesium-137. We have stated that net natural background did not seem to vary with subject height, weight, or sex. This implies that at each counting location, using calibrated crystals, one can calculate a radiation dose index for a group of the residents:

$$r_i = m\left(\frac{\text{sum of gross CPM}}{n} - \text{BKGD}\right) \quad (11)$$

where m is the detector sensitivity, (mrad/a● CPM), usually 0.030–0.033 for 7.5 x 7.5 cm crystals

BKGD is the net background count rate calculated for a human subject containing no cesium–137;

r_i is the "radiation dose index" in mrad/a for the counting location;

Sum of gross CPM is the sum of the gross cesium counts per minute for all subjects;

and n is the number of subjects at the counting location.

The radiation dose index for the group can be calculated directly from the net counting data and does not involve intermediary calculations of individual cesium concentrations or knowledge of the body weights.

Summary and conclusions

During April and May 1967, cesium–137 concentrations were measured by the National Center for Radiological Health, Public Health Service, in 1,334 residents of 13 Alaskan villages and cities where caribou and reindeer are major sources of meat. Unshielded 7.5 x 7.5 cm NaI(Tl) scintillation detectors, held in the lap, were used for subjects of both sexes, from 4 to 91 years old, weighing 16 to 100 kilograms. The overall cesium–137 concentrations were:

Sex	Number of subjects	Weight range (kg)	Cesium-137 concentrations (nCi/kg)	
			Group average	Individual maximum
Male	252	16–45	4.20	16.58
	196	46–65	5.72	19.30
	250	>65	6.38	20.76
Female	231	16–45	4.35	15.62
	285	46–65	4.87	18.21
	120	>65	3.22	12.92

No cesium–134 was detected.

Cesium–137 concentrations were highest in Ambler, Selawik, Noorvik, Shungnak and Anaktuvuk Pass, intermediate in Shishmaref, Noatak, Mekoryuk, Egegik and Teller, and lowest in three coastal cities where whaling is done (Wainwright, Point Hope and Barrow).

The Bureau of Indian Affairs school lunch program, where practiced, did not appear to reduce significantly the cesium–137 concentrations in children. Average concentrations in men who were measured both years at Anaktuvuk Pass dropped 37.5 percent from 1966 to 1967; Selawik males showed a 15.7 percent decrease, while cesium–137 concentrations in adult male residents of Egegik increased 2 percent.

The Federal Radiation Council has discussed guidance with regard to the need for protective actions to reduce cesium–137 concentrations in Alaskans (*1*). They have concluded that the applicable Radiation Protection Guide is 0.5 rad per year because the cesium–137 in the groups of interest is being measured directly. The data given in table 7 show that comparable 1967 values were almost consistently lower than those for 1966, and in neither year did the group averages equal or exceed one-third of the Radiation Protection Guide. The highest individual values listed in table 2 (1967), 21 nCi/kg in an 82 kg man (0.17 rad/year), and table 3 (1966), 32 nCi/kg in a 68 kg man (0.26 rad/year), were below the RPG, indicating that while surveillance should be continued, no protective action is necessary at this time.

REFERENCES

(*1*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards—protective action guides for strontium–89, strontium–90 and cesium–137. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1965) pp. 42–44.

(*2*) HANSON, W. C., H. E. PALMER, and B. I. GRIFFIN. Environment of the Cape Thompson Region, Alaska, Chapter 41. Norman J. Wilinovsky, Editor (1966), U.S. Atomic Energy Commission, Division of Technical Information.

(*3*) PALMER, H. E., and W. C. ROESCH. A shadow shield whole-body counter. Health Physics 11:1213–1219 (1965).

(*4*) HANSON, W. C., H. E. PALMER, and B. I. GRIFFIN. Radioactivity in northern Alaskan Eskimos and their foods, summer 1962. Health Physics 10:421–429 (June 1964).

(*5*) MOHINDRA, V. K., and J. H. GORDON. Cesium-137 levels in the Canadian north, January–June 1965. Radiation Protection Division, Canadian Department of National Health and Welfare 3:3–12 (October 1965).

(*6*) KOREN, K., and A. STROMME. Cesium-137 body burden in persons chosen at random from selected areas in Norway. Nature 200:278–279 (October 19, 1963).

(*7*) LIDEN, K., and M. GUSTAFSSON. Relationships and Seasonal Variation of Cesium-137 in Lichen, Reindeer and Man in Northern Sweden, 1961 to 1965. Radioecological Concentration Processes—Proceedings of an International Symposium held in Stockholm, 25–29 April 1966. Bertil Aberg and Frank P. Hungate, Editors. Pergamon Press (1966).

(*8*) MIETTINEN, J. K., A. JOKELAINEN, P. ROINE, K. LIDEN, Y. NAVERSTEN. Cesium-137 and potassium in people and diet—a study of Finnish Lapps. Ann Acad Sci Fennicae, AII. Chemica 120: 3–46 (1963).

(*9*) NEVSTRUEVA, M. A., A. A. MOISEEV, D. K. POPOV, and R. V. RAMZAEV. Characteristics of the radioactive pollution of the biological chain "Moss-Reindeer-Man" in the northern region of the USSR from 1961 through 1964. The Government Committee on the Utilization of Atomic Energy, USSR, Moscow (U.N. Document A/AC.82/G/L.1027) (1964).

(*10*) PALMER, H. E., and R. W. PERKINS. Cesium-134 in Alaskan Eskimos and in fallout. Science 142: 66–67 (1963).

(*11*) LIDEN, K., and I. O. ANDERSON. Cesium-134 in man. Nature 195:1040–1043 (September 15, 1962).

(*12*) BRUCE, D. W., D. G. REMARK, and W. J. AVERETT. Cesium-137 body burdens of Alaskan men, spring 1965. Public Health Rep 80:949–953 (November 1965).

(*13*) FITZPATRICK, D. E. P., J. L. RUSSELL, O. G. BRISCOE, and C. R. CALVERT. Cesium-137 body burdens in Alaskan men, spring 1966. Radiological Health Data Rep 7:691–696 (December 1966).

(*14*) HANSON, W. C. Cesium-137 in the food chain of Eskimos. Pacific Northwest Laboratory annual reports for 1966 (BNWL–480) and for 1965 (BNWL–280) to the USAEC Division of Biology and Medicine. Vol. I, Biol Sci (July 1967 and January 1966, respectively.)

(*15*) CHANDLER, R. P., and D. R. SNAVELY. Summary of cesium-137 and strontium-90 concentrations reported in certain Alaskan populations and foodstuffs 1961–1966. Radiol Health Data Rep 7:675–689 (December 1966).

(*16*) HANSON, W. C. Strontium-90 and cesium-137 in Alaskan Arctic ecosystems. Hearings before the subcommittee on Research Development and Radiation of the Joint Committee on Atomic Energy, U. S. Congress, June 29 and 30, 1965, pp. 35–54.

(*17*) PALMER, H. E. Simplified whole body counting. Health Physics 12:95–96 (January 1966).

(*18*) LEDERER, C. M., J. M. HOLLANDER and I. PERLMAN. Table of isotopes, 6th Edition (1967). John Wiley & Sons, Inc., N. Y. p. 285.

(*19*) Reference 18—*ibid.* p. 282.

(*20*) Reference 18—*ibid.* p. 174.

(*21*) NICHOLSON, W. L. Statistics of net-counting-rate estimation with dominant background corrections. Nucleonics 24:118–121 (August 1966).

(*22*) MIETTINEN, J. K. Cesium-137 in Groups of Populations. Assessment of Radioactivity in Man, Vol. II, Proceedings of Symposium held at Heidelberg May 11–16, 1964. IAEA, Vienna, Proceeding series (STI/PUB/84) (Vol. II) CONF. 448 (Vol. II) (November 1964).

(*23*) MATSUMOTO, W. Y. Evaluation of the accuracy of decay scheme constants and calibration standards for cesium-137. BNWL–87, Pacific Northwest Laboratory, Richland, Wash. (July 1965).

Technical Notes

Alpha Radiation Exposure Levels in Underground Uranium and Other Mines

Bureau of Mines[1]
Department of the Interior

Surveys of radon daughter concentrations in air in underground uranium mines were begun by the Bureau of Mines in the early 1950's when the U.S. Public Health Service first warned of the potential hazard of lung cancer due to ionizing radiation.

For more than 15 years, inspections, including surveys of radon daughter concentration, have been conducted in uranium mines on Indian lands. From 1959 through March 30, 1962, when they were closed, mines on Atomic Energy Commission withdrawn lands[2] were also inspected by the Bureau of Mines. In 1961, at the request of the Industrial Commission, State of Utah, the Bureau aided in establishing a State uranium mine radiation control program. Bureau engineers and Utah State mine inspectors jointly inspected all operating uranium mines in Utah at least once.

During 1962 and 1963, under Public Law 87–300, the Department of the Interior, acting through the Bureau of Mines, was charged with responsibility for reporting to the Congress on health and safety conditions in all the Nation's noncoal mines including uranium mines. During this period, radon-daughter concentrations were measured on two occasions in each of the larger underground uranium mines and in most of the smaller ones.

Individual reports were issued covering the inspections and surveys made in this period. Table 1 summarizes the radon daughter concentrations expressed as working levels[3] found from 1959 to 1963. Prior to 1962 only working places were sampled and full-shift exposure rates were not estimated. Since 1962, full-shift exposure rates have been estimated for individual underground workers based on development of a spot-check time-weighted method (*1*) as result of a special study conducted in 10 mines during October 1960 through May 1961.

Procedure

Radon daughter sampling was performed using the conventional filtered-air method (*2*). Mine air was drawn through filter papers at a measured rate by a pump for a 5 or 10-minute period. After allowing the particulates collected on the filters to age at least 40 minutes, alpha radioactivity was measured using a calibrated scintillation-type field counter. Alpha radioactivity at the time of measurement was converted to potential alpha-particle energy at the time of sampling by dividing disintegrations per minute by the number of liters sampled and multiplying by the elapsed time factor (*2*).

---

[1] Summarized from "Mineral Industry Surveys, Health and Safety Summary," prepared by the staff of the Division of Accident Prevention and Health, Bureau of Mines, Washington, D.C., May 1968, and "Mineral Industry Surveys, Health and Safety Summary" prepared by Donald K. Walker, technical assistant, Health and Safety District E, Bureau of Mines, Denver, Colo., August 1968.

[2] Lands withdrawn from the public domain for AEC use.

[3] One "working level" is defined as any combination of radon daughters in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha-particle energy. The numerical value of the working level is derived from the alpha-particle energy released by the total decay of the short-lived radon daughter products at radioactive equilibrium with 100 pCi of radon–222 per liter of air.

Table 1. Radon-daughter concentrations found during various surveys

Survey	Number of mines	Total number of working places	Number of working places within working level range					
			0–0.3	0–1.0	0–3.0	0–5.0	1–10.0	0–10.0 +
1959–61 mines on Indian land and AEC with drawn land	(1st inspection) 50	93	(a)	15 [b] (16)	33 (35)	(c)	68 (73)	93 (100)
	(2nd inspection) 33	94		37 (39)	64 (68)	(c)	82 (87)	94 (100)
	(3rd inspection) 29	86		41 (48)	56 (65)	(c)	77 (90)	86 (100)
	(4th inspection) 21	85		23 (27)	57 (67)	(c)	76 (89)	85 (100)
	(5th inspection) 19	88		22 (25)	51 (58)	(c)	80 (91)	88 (100)
	(6th inspection) 10	64		15 (23)	36 (56)	(c)	56 (88)	64 (100)
	(7th inspection) 4	13		4 (31)	8 (62)	(c)	13 (100)	—
		Estimated average full-shift exposure rates						
		Number of men exposed	Number of men exposed within working level range					
PL 87-300 (1962–63)	(1st inspection) 139	2,213	(a)	1,007 (45)	1,634 (74)	1,946 (88)	2,104 (95)	2,213 (100)
	(2nd inspection) 119	2,242	(a)	978 (44)	1,653 (74)	1,907 (85)	2,158 (96)	2,242 (100)

[a] No results in given working level range.
[b] Values in parentheses are percent of working places or men in given working level range.
[c] Data for this range of exposures was not recorded prior to 1961.

Individual samples were taken in all occupied mine areas. A time study was made to allow individual samples to be time weighted into average full-shift exposure rates for each miner or group of miners (*1*).

Detailed ventilation-radiation level studies were made in six of the larger underground uranium mines in April through September 1967. These studies were designed specifically to reveal the relationships between ventilation and working levels which existed in the mines. Each detailed study required tracing and measuring the ventilating air both quantitatively and qualitatively (for alpha radiation from airborne particulates) from the point where fresh air entered the mine to where the air was distributed in production areas and finally where return air was exhausted at the surface. Although these studies were very time consuming, after all the information was assembled, a clear picture of the relationships being sought was afforded. Conditions were described and recommendations for reducing working levels were developed (table 2).

Table 2. Summary of recommended ventilation changes to reduce radiation levels in six underground uranium mines in which detailed ventilation-radiation surveys were conducted in 1967

Recommendation	Number of times recommendation was made
Provide and maintain auxiliary ventilation	10
Eliminate recirculation	10
Seal old workings	3
Increase primary ventilation	3
Additional openings required	2
Responsibility for insuring that all fans are operating while men are underground should be designated	1

Recent survey data

On March 30, 1967 the Bureau of Mines began the latest survey of radiation exposure rates experienced by miners in all the nation's underground uranium mines. These data were collected during radiation surveys made by mining engineers of Health and Safety District E, Bureau of Mines, Denver, Colo., and the Phoenix, Ariz., and Salt Lake City, Utah subdistrict offices. Surveys were made in uranium mines in Arizona, California, Colorado, New Mexico, South Dakota, Utah, and Wyoming.

Table 3. Estimated full-shift exposure rates to radon daughters, April 1–June 30, 1967 [a]

Average exposure rates (working levels)	Mines employing more than four men			Mines employing four men or less			Total of all mines		
	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent
0–0.3	313	28.7	28.7	71	38.0	38.0	384	30.1	30.1
0.4–1.0	336	30.9	59.6	34	18.2	56.2	370	29.0	59.1
1.1–3.0	256	23.5	83.1	57	30.5	86.7	313	24.5	83.6
3.1–5.0	89	8.2	91.3	12	6.4	93.1	101	7.9	91.5
5.1–10.0	80	7.3	98.6	9	4.8	97.9	89	7.0	98.5
>10	15	1.4	100.0	4	2.1	100.0	19	1.5	100.0
Total	1,089	100.0		187	100.0		1,276	100.0	

[a] 119 original surveys.

Table 4. Estimated full-shift exposure rates to radon daughters, July 1–September 30, 1967 [a]

Average exposure rates (working levels)	Mines employing more than four men			Mines employing four men or less			Total of all mines		
	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent
0–0.3	202	21.5	21.5	53	39.3	39.3	255	23.7	23.7
0.4–1.0	322	34.2	55.7	30	22.3	61.6	352	32.7	56.4
1.1–3.0	351	37.3	93.0	33	24.4	86.0	384	35.7	92.1
3.1–5.0	44	4.7	97.7	8	5.9	91.9	52	4.8	96.9
5.1–10.0	22	2.3	100.0	8	5.9	97.8	30	2.8	99.7
>10	....	....	....	3	2.2	100.0	3	0.3	100.0
Total	941	100.0		135	100.0		1,076	100.0	

[a] 47 original surveys and 30 resurveys.

Table 5. Estimated full-shift exposure rates to radon daughters, October 1–December 31, 1967 [a]

Average exposure rates (working levels)	Mines employing more than four men			Mines employing four men or less			Total of all mines		
	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent
0–0.3	66	25.2	25.2	50	45.9	45.9	116	18.3	31.3
0.4–1.0	154	58.8	84.0	37	33.9	79.8	191	51.5	82.8
1.1–3.0	36	13.7	97.7	21	19.3	99.1	57	15.4	98.2
3.1–5.0	6	2.3	100.0	1	0.9	100.0	7	1.8	100.0
5.1–10.0	....	....		....	....		....	....	
>10	....	....		....	....		....	....	
Total	262	100.0		109	100.0		371	100.0	

[a] 10 original surveys and 48 resurveys.

Table 6. Estimated full-shift exposure rates to radon daughters, January 1–March 31, 1968 [a]

Average exposure rates (working levels)	Mines employing more than four men			Mines employing four men or less			Total of all mines		
	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent
0–0.3	384	36.1	36.1	30	54.5	54.5	414	37.0	37.0
0.4–1.0	421	39.6	75.7	11	20.0	74.5	432	38.6	75.6
1.1–3.0	207	19.5	95.2	11	20.0	94.5	218	19.5	95.1
3.1–5.0	35	3.3	98.5	2	3.7	98.2	37	3.4	98.5
5.1–10.0	16	1.5	100.0	1	1.8	100.0	17	1.5	100.0
>10	....	....		....	....		....	....	
Total	1,063	100.0		55	100.0		1,118	100.0	

[a] 8 original surveys and 32 resurveys.

179

Table 7. Estimated full-shift exposure rates to radon daughters, April 1–June 30, 1968[a]

Average exposure rates (working levels)	Mines employing more than four men			Mines employing four men or less			Total of all mines		
	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent
0–0.3	295	44.9	44.9	63	63	63	358	47.3	47.3
0.4–1.0	269	40.9	85.8	21	21	84	290	38.3	85.6
1.1–3.0	71	10.8	96.6	10	10	94	81	10.7	96.3
3.1–5.0	12	1.8	98.4	3	3	97	15	2.0	98.3
5.1–10.0	1	0.2	98.6	3	3	100	4	0.5	98.8
>10	9	1.4	100.0				9	1.2	100.0
Total	657	100.0		100	100		757	100.0	

[a] 23 original surveys and 40 resurveys.

All active underground uranium mines were surveyed once and most have been resurveyed. Not all mines were surveyed in any one quarter. The selection of mines surveyed in a period was not completely random. However, enough mines were surveyed each quarter to give an industry-wide picture.

Data collected through June 30, 1968, during original surveys and resurveys of these mines are summarized in tables 3 through 7, by quarter years for comparison purposes. The steady improvement is indicated in the quarterly results given in tables 3 through 7. Table 3 shows that full-shift exposure rates were less than one working level for 59.1 percent of the miners evaluated in the first quarter of sampling (April 1–June 30, 1967), and table 7 shows this figure increased to 85.6 percent for the last quarter sampled (April 1–June 30, 1968).

Because of the Secretary of Labor's June 12, 1967, issuance of an exposure standard of 0.3 working level month[4] for operations subject to the Walsh-Healey Public Contract Act (*3*), the data are summarized so as to allow evaluation in terms of the Secretary of Labor's standard as well as in terms of the exposure standard of 1.0 working level month tentatively recommended by the Federal Radiation Council (*4*).

Table 8 summarizes suggestions given in the initial survey reports for reducing working levels in 197 mines. Table 9 is a summary of suggested ventilation changes to reduce working levels in 136 mines surveyed twice.

Table 8. Summary of suggested ventilation changes to reduce alpha radiation levels in initial surveys of 197 underground uranium mines[a]

Suggestion	Number of times suggestion was recorded		
	127 mines employing four men or less	70 mines employing more than four men	Total 197 mines
Provide and maintain auxiliary ventilation	46	33	79
Eliminate recirculation and short circuiting	12	19	31
Seal old workings	31	26	57
Increase air volume by larger fan, adjustment of fan or additional fan	36	27	63
Provide mechanical ventilation	11	1	12
Additional openings required	14	28	42
Total	150	134	284

[a] This is a subjective compilation adequate only to give a broad general picture. Specific recommendations were not made in radiation survey reports; information in this table is gleaned from summary discussions in the reports.

Nonuranium mines

To determine the extent of the alpha radiation problem in mines other than uranium, radon-daughter samples have been taken in several nonuranium mines. These data are compiled in tables 10 and 11. The data listed in table 10 were collected during environmental dust surveys conducted from 1958 to 1961. The data in table 11 were collected from September 1, 1967 through May 10, 1968.

Indications to date are that current conditions in nonuranium mines are generally adequate to meet a 1.0 working level standard. However, spot sampling for radon daughter concentrations will eventually apply to all underground mines in the United States for a full assessment of the potential health problem to underground miners.

---

[4] A working level month is defined as the exposure received by a worker breathing air at one working level concentration for 4⅓ weeks of 40 hours each.

Table 9. Summary of suggested ventilation changes to reduce alpha radiation levels comparing initial surveys with resurveys of 136 underground uranium mines [a]

Suggestion	Number of times suggestion was recorded											
	74 mines employing four men or less				62 mines employing more than four men				Total, 136 mines			
	Initial survey	Resurvey			Initial survey	Resurvey			Initial survey	Resurvey		
		Adopted	Repeated	New		Adopted	Repeated	New		Adopted	Repeated	New
Provide and maintain auxiliary ventilation	31	8	15	16	32	6	25	14	63	14	40	30
Eliminate recirculation and short circuiting	10	3	3	8	18	4	4	11	28	7	7	19
Seal old workings	21	1	12	13	26	6	11	14	47	7	23	27
Increase air volume by larger fan, adjustment of fan or additional fan	26	5	12	16	27	7	11	15	53	12	23	31
Provide mechanical ventilation	4	3	-------	1	1	-------	1	1	5	3	1	2
Additional openings required	12	-------	3	5	28	7	10	5	40	7	13	10
Total	104	20	45	59	132	30	62	60	236	50	107	119

[a] This is a subjective compilation only. Radiation survey and resurvey reports do not present specific recommendations and adopted suggestions are not always reported. Information in this table was gleaned from summary discussions in the reports and is not complete.

Table 10. Radon-daughter sampling in nonuranium mines, 1958–1961

Commodity	Number of mines	Number of samples	Working levels
Chromate	1	4	< 0.1
Copper	7	22	< .1
		5	.2
		2	.3
		2	.7
		1	1.0
Gold	1	5	< .1
Gold-silver	1	3	< .1
Iron	6	20	< .1
		2	.2
		2	.3
Lead-silver	3	10	< .1
Lead-zinc	8	21	< .1
		1	.3
		4	.5
Manganese	1	3	< .1
Mercury	3	4	Nil
		6	< .1
Molybdenum	1	2	< .1
		1	.3
Pyrite	1	several	< .1
Tungsten, copper, molybdenum	1	1	< .1
		1	.8
		1	[a] 18.7
Total	34	+123	

[a] Unventilated area.

Table 11. Radon-daughter sampling in nonuranium mines, 1967–1968

Commodity	Number of mines	Number of samples	Working levels
Coal	9	63	Nil
Fluorspar	1	3	<0.1
Molybdenum	1	4	Trace
			< .1
Tungsten, copper, molybdenum	1	1	.5
		3	.4
		1	.3
		1	.1
		3	< .1
Gold	1	5	Trace
			< .1
Potash	3	9	Nil
Trona	3	3	Trace
			< .1
		16	Nil
Phosphate rock	1	1	.6
		2	.3
		3	.2
		2	.1
Clay	1	1	.2
		6	< .1
		1	Nil
Lead-zinc	2	1	.4
		1	.3
		5	.2
		5	< .1
		2	Nil
Total	23	142	

Acknowledgement

The cooperation of mining companies and their personnel in facilitating the collection of radon-daughter samples and obtaining related data is gratefully acknowledged. State inspection personnel frequently accompanied Bureau of Mines engineers during the surveys and studies and their efforts and cooperation were very helpful.

REFERENCES

(*1*) BATES, R. C., and R. L. ROCK. Estimating daily exposures of underground uranium miners to airborne radon-daughter products. Bureau of Mines Report of Investigations 6106 (1962) p. 22.

(*2*) HOLADAY, D. A., D. E. RUSHING, R. D. COLEMAN, P. F. WOOLRICH, H. L. KUSNETZ, and W. F. GALE. Control of radon and daughters in uranium mines and calculations on biologic effects, PHS Publication No. 494. U.S. Department of Health, Education, and Welfare (1957) pp. 32–42.

(*3*) DEPARTMENT OF LABOR. Standards for Uranium Mining, Amendment of June 9, 1967. Federal Register 67–6687 of June 12, 1967.

(*4*) FEDERAL RADIATION COUNCIL. Radiation protection guidance for federal agencies. Memorandum for the President, July 21, 1967. Federal Register 67–9037 of July 31, 1967.

Alpha Radioactivity in Coal Mine Drainage in Western Pennsylvania

Roger D. Caldwell, Ronald F. Crosby and *M. Paul Lockard*[1]

Most health groups at nuclear facilities, in addition to their regulatory responsibility to monitor the effluents from the facility, monitor the offsite environment. This is done to (1) determine the effectiveness of their effluent monitoring, (2) determine the level of offsite exposure and (3) provide a background base in case of an accidental release. The Nuclear Materials and Equipment Corporation (NUMEC) samples Kiskiminetas River at weekly intervals (in addition to the routine air, fallout and vegetation monitoring), as the effluent from NUMEC is emptied into this river.

The NUMEC nuclear fuel plants are located about 30 miles northeast of Pittsburgh. The Kiskiminetas River flows into the Allegheny River just north of Pittsburgh (figure 1). The plutonium plant is about 10 miles up the Kiskiminetas River near Leechburg; the uranium plant is in Apollo, 5 miles farther upstream.

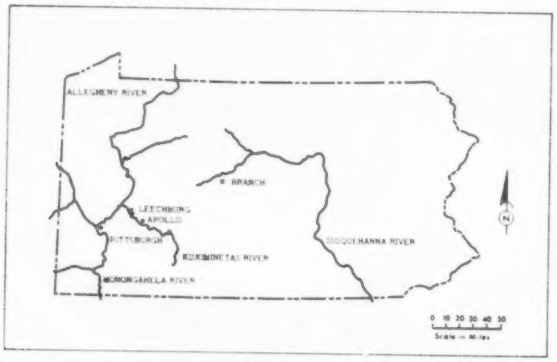

Figure 2. Physiographic divisions of Pennsylvania

Origin of natural radioactivity in coal mine drainage

Coal mining—once the principal industry—is still an important industry in western Pennsylvania. Several authors have referred to the association between uranium and coal in mines (*1–7*). Large reserves of uranium-bearing coal and lignite are known in western North and South Dakota and southeastern Montana. In 1954, considerable tonnages of ore-grade uraniferous lignite were discovered in the Cave Hills area of western South Dakota (*6*). These western United States discoveries led the U.S. Geological Survey to explore eastern coal reserves for uranium occurrences (*2, 3*). Uranium was found in uneconomic concentrations in Pennsylvania coal. Estimates ranged from 10 to 140 parts per million, although some eastern Pennsylvania sedimentary deposits contain up to 0.3 percent U_3O_8 (*1*).

The coexistence of uranium and coal is explained by the descending meteoric hypothesis for uranium occurrences (*1*). Downward moving solutions leached small amounts of uranium and other metals from syngenetic accumulations in the overlying sediments and these metals ultimately were precipitated in carbonaceous zones by organically produced hydrogen sulfide.

Survey and analytical methods

Samples were taken from the Kiskiminetas River at three sites to determine the alpha radioactivity concentration. The sampling sites at Apollo, Leechburg, and Vandergrift are above the uranium plant, below the plutonium plant and between the two plants, respectively. The average radioactivity concentrations for 1966 are given in table 1. Since nuclear fuel radionuclides are alpha-particle emitters, only alpha radioactivity levels are reported.

---

[1] Mr. Caldwell is manager, Health and Safety Department; Mr. Crosby is an environmental monitoring specialist and Mr. Lockard is a radiological services technician; Nuclear Materials and Equipment Corporation; Apollo, Pa. 15613.

Table 1. Alpha radioactivity concentrations on the Kiskiminetas River, 1966

Sampling location	Concentration (pCi/liter)		
	Minimum	Maximum	Average
Apollo	0.8	102.7	13.14
Vandergrift	.45	101.0	13.36
Leechburg	.9	46.0	10.77

The average gross alpha-particle concentrations observed in the Kiskiminetas River are higher than for most eastern U.S. rivers (*8*). Since the average flow in the Kiskiminetas River is more than 3,000 cubic feet per second (as determined by the Hydrology Section of the Army Corps of Engineers, Federal Building, Pittsburgh, Pa.), the weighted concentration at Apollo represents about 100 millicuries per day. This is 20 times the radioactivity that would be permitted to be released per day from both plants.

Since concentrations of alpha radioactivity range from tenths of a picocurie per liter to more than 100 pCi/liter, the upstream source apparently was fluctuating. Figure 2 shows the monthly average concentration for all three locations. The calculated millicuries per day show that the total radioactivity per day is a function of both the flow rate and concentration but appear to depend more on the flow rate than the concentration.

A 2-day survey by canoe of the Kiskiminetas River watershed was undertaken in May 1966 to determine the cause of the upstream radioactivity. The survey was repeated in June 1967 and additional surveys of the west branch of the Susquehanna River were done in August and November of 1967.

The Kiskiminetas River watershed contains a number of coal mines, whose drainage creates a high acid content (pH = 2-5) in the Kiskiminetas River. Geological publications have described the association of uranium and coal in western Pennsylvania (*1–3*). Since coal mine drainage might be the source of upstream radioactivity, water from several mines was sampled.

Figure 3 shows the detail of the 1966 survey. River samples were taken from the Allegheny to the Loyalhanna reservoir. All large sidestreams were sampled and samples were obtained directly from two mines and a boney pile. The term "boney pile" refers to the shale overcover removed from coal. Most of the river samples were obtained from canoes or flat-bottomed fishing boats, since the Kiskiminetas River has a shallow draft from late spring to fall.

One-liter samples were collected at each location. The acidity of each sample was tested with wide range pH test strips or field pH meters. Most mines and sidestreams showed high acidity. The Kiskiminetas River is one of the more acid rivers in Pennsylvania.

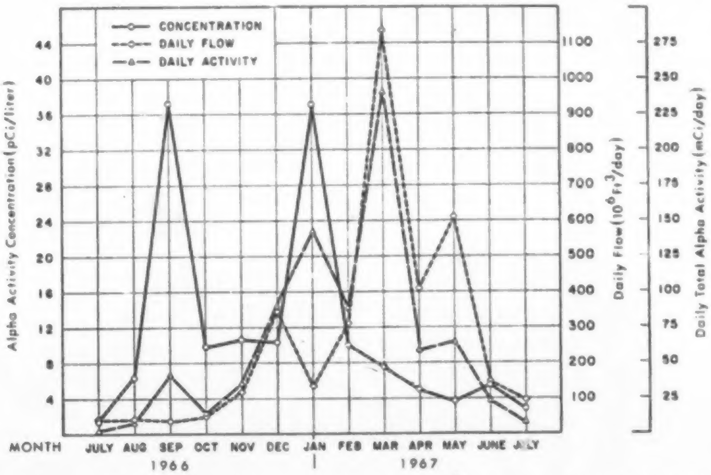

Figure 2. Alpha radioactivity in the Kiskiminetas river, July 1966–July 1967

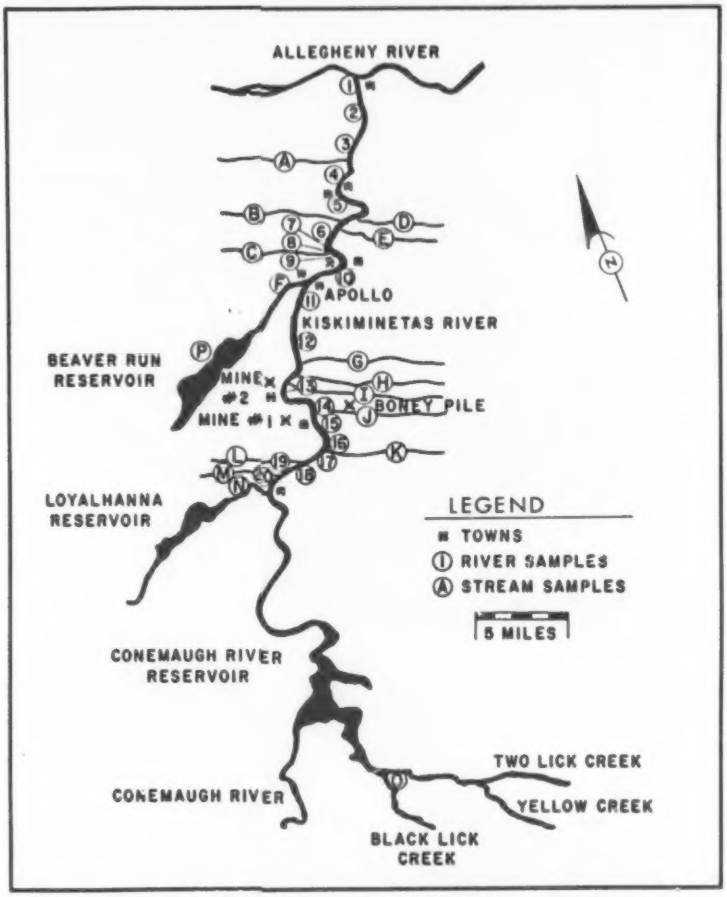
ALLEGHENY RIVER
APOLLO
KISKIMINETAS RIVER
BEAVER RUN RESERVOIR
MINE #2
MINE #1
BONEY PILE
LOYALHANNA RESERVOIR
LEGEND
TOWNS
RIVER SAMPLES
STREAM SAMPLES
5 MILES
N
CONEMAUGH RIVER RESERVOIR
TWO LICK CREEK
YELLOW CREEK
CONEMAUGH RIVER
BLACK LICK CREEK

Figure 3. Radioactivity survey on the Kiskiminetas river

The samples were analyzed for gross alpha radioactivity following the general procedures used by the Public Health Service (4). The suspended matter was removed by centrifugation and filtration. The filtered water samples were treated with 1 $\underline{N}$ HNO_3 to digest organic matter evaporated to low volume and transferred to stainless-steel planchets for counting. The planchets were flamed to dull red, cooled and weighed. Alpha-particle counting was done in an alpha scintillation counter whose background never exceeded one count per minute or a gas proportional counter whose background never exceeded 0.3 count per minute. All samples were counted for at least 10 minutes. Correction was made for self-absorption for samples exceeding 10 mg/cm^2.

Suspended solids in the samples were also analyzed for alpha radioactivity. While self-absorption uncertainties were present, most of the radioactivity appeared in the dissolved solids.

Results

The results of the May 1966 survey of the Kismiminetas River watershed are given in table 2. The levels of radioactivity concentrations in coal mine drainage are appreciable considering that the MPC_w for unidentified radionuclides is 10 pCi/liter. Radiochemical analyses were done on several samples. Alpha-particle emitters were determined by alpha spectroscopy except that radium–226 was determined by the radon emanation technique. The radioactivity was found to be predominantly

184

Table 2. Kiskiminetas River watershed alpha radioactivity survey, May 1966

Sampling point[a]	Concentration (pCi/liter)	Remarks
River: 1	2.7	Allegheny River
2	18.9	
3	26.9	
4	45.2	
5	25.5	
6	28.2	
7	142.7	Old mine drainage
8	16.8	
9	33.6	
10	17.3	
11	46.4	Downstream of principal mine drainage
12	119.1	Downstream of principal mine drainage
13	81.8	Downstream of principal mine drainage
14	11.8	
15	3.6	
16	14.5	
17	16.4	
18	17.3	
19	12.7	
20	1.8	Upstream of all mines
Stream: A	32.7	Mine drainage
B	30.5	Mine drainage
C	21.6	
D	29.3	
E	20.5	
F	12.7	
G	1.0	
H	2.9	
I	1.0	
J	163.6	Downstream of boney pile
K	1.0	
L	10.0	
M	15.5	
N	4.5	Upstream of all mines
O	3.4	Upstream of all mines
P	17.3	Reservoir, some mine drainage
Mine # 1	174.1	
Mine # 2	120.0	
Boney pile	180.0	Shale overcover of coal

[a] See figure 3 for sampling point location.

Table 3. Kiskiminetas River watershed, alpha radioactivity survey, June 1967

Sample location	Concentration (pCi/liter)
Conemaugh reservoir	9.1
Mine stream, 1 mile below dam	24.5
Side stream, 2 miles below dam	15.4
Side stream, 3 miles below dam	10.0
Side stream at Deep Rapids	20.0
River, Saltsburg	16.4
Mine stream, Saltsburg	31.8
Fresh stream, 1 mile below Saltsburg	0.9
Side stream, 1.5 miles below Saltsburg	8.2
Mine stream, 2 miles below Saltsburg	24.5
Mine drainage, 2 miles below Saltsburg	14.5
Mine stream, Salina	32.7
Mine drainage, Brownstown	7.3
Mine drainage, 1 mile below Brownstown	19.1
Mine drainage, 1.5 miles below Brownstown	27.3
Beaver Run, W. Apollo	9.1
Mine stream, N. Apollo	41.8
Pine Run Creek	6.4
Side stream, River Road	8.2
Mine drainage, N. Vandergrift	12.7
Stitt's Run	11.8
Storm culvert #1	3.2
Storm culvert #2	3.6
Hungry Hollow Creek	18.2
Fresh water spring, Leechburg	ND
Mine stream, Leechburg	60.0
Mine stream, Baghdad #1	21.8
Mine stream, Baghdad #2	53.6
Strip mine, 2 miles above Allegheny River	32.7
Strip mine stream	30.9
Side stream Kiski Junction	11.8

ND, nondetectable.

uranium–234 and uranium–238; less than 10 percent was from radium–226.

The increased levels of radioactivity appear to be only associated with coal mine drainage. River samples 1 and 20, and stream samples G, H, I, K, N, and O are all upstream from mine drainage and all are low in gross alpha radioactivity.

The Kiskiminetas River watershed survey was repeated in June 1967. The results are given in table 3. Only sidestream samples were taken on this survey to gain additional detail over the 1966 survey. While not as dramatic as the 1966 data, the 1967 data confirmed the high concentrations in coal mine drainage.

A review of the Pennsylvania geological literature indicates that other watersheds might contain radioactivity from mine drainage. Consequently, the west branch of the Susquehanna River was surveyed in August and November 1967. Results of this survey are in table 4. It is immediately apparent that the Susquehanna watershed is much less radioactive. However, this may be misleading since many of the samples were collected following heavy rains. In any case, the higher radioactivity in some of the coal mine drainage is evident.

Table 4. West Branch, Susquehanna River watershed alpha radioactivity survey, August and November 1967

Sample location	Concentrations (pCi/liter)
Mine drainage, W. Decatur	ND
Moshannon Creek, Phillipsburg	1.66
Moshannon Creek, Route 153	0.77
Lick Run, Shawsville	11
Deep Mine drainage, Osceola Mills	14.55
Susquehanna River, Clearfield (above mine pollution)	ND
Susquehanna River, above Shawsville power station	ND
Susquehanna River, below Shawsville	.31
Trout Run, Mine stream	.31
Mine Settling Ponds, Karthaus	2.47
Mosquito Creek, unpolluted	ND
Deer Creek, unpolluted	ND
Shintown Run, Mine Stream	ND
Kettle Creek, Mine Stream	.33
Cooks Run, Mine Stream	2.66
Strip Mine, Chilcote farm	8.06
Indian Caverns	ND

ND, nondetectable

REFERENCES

(1) McCAULEY, J. F. Uranium in Pennsylvania. Pennsylvania Geological Survey, Bulletin M 43 (1961).

(2) FERM, J. C. Radioactivity of coals and associated rocks in Beaver, Clearfield and Jefferson Counties, Pennsylvania. U.S. Geological Survey, TEI-468 (January 1955).

(3) PATTERSON, E. D. Radioactivity of part of the bituminous coal region of Pennsylvania. U.S. Geological Survey, TEI-49 (November 1954).

(4) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Radioassay Procedures for Environmental Samples, PHS Publication No. 999-RH-27. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (January 1967).

(5) FAUL, H. Nuclear Geology. John Wiley and Sons (1954).

(6) U.S. ATOMIC ENERGY COMMISSION and U.S. GEOLOGICAL SURVEY. Prospecting for uranium. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (1957).

(7) U.S. GEOLOGICAL SURVEY. Geology of Uranium and Thorium, Vol. 6. Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Columbia University Press (1956).

(8) EISENBUD, M. Environmental Radioactivity. McGraw-Hill Publishing Company, New York, N.Y. (1963).

130

SECTION I. MILK AND FOOD

Milk Surveillance[1]

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long term concentration trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network, sponsored by the National Center for Radiological Health and the National Center for Urban and Industrial Health, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments have also initiated local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

> Pan American Milk Sampling Program (Pan American Health Organization and the U.S. Public Health Service)—5 sampling stations,
>
> Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations.

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Detailed sampling locations provided for by the State networks are presented in another section of this report.

Based on the similar purpose for these sampling activities, a format has been developed to integrate the complementary data that are routinely obtained by these several milk networks. To do this, it was necessary (1) to determine whether the data being generated by the various laboratories were accurate and satisfactorily comparable and (2) to develop a common reporting basis. A discussion of existing radiation protection guidance applicable in the United States is also included, in order to place the significance of the U.S. data reported in perspective.

---

[1] Special report prepared by Marvin Rosenstein, senior technical editor, Radiological Health Data and Reports, with the assistance of Warren A. Brill, technical editor, Radiological Health Data and Reports, and Mary H. Nesdore, public health analyst, Radiation Exposure Intelligence Section, Standards and Intelligence Branch, National Center for Radiological Health.

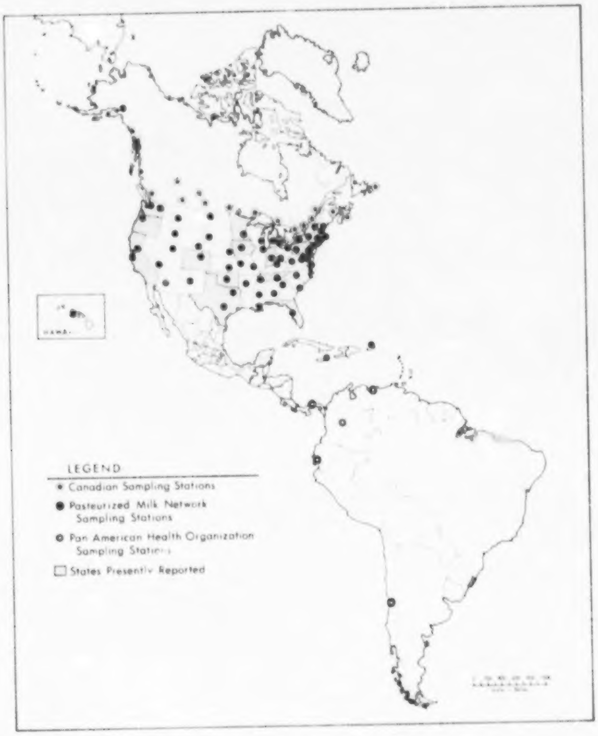
HAWAII
LEGEND
● Canadian Sampling Stations
● Pasteurized Milk Network Sampling Stations
◉ Pan American Health Organization Sampling Stations
☐ States Presently Reported

Figure 1. Milk sampling networks in the western Hemisphere reported in *Radiological Health Data and Reports*

Radionuclide and element coverage

Experience has established that relatively few of the many radionuclides occurring or formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium–89, strontium–90, iodine–131, cesium–137, and barium–140. A sixth radionuclide, potassium–40, occurs naturally in 0.0118 percent abundance of the element potassium (*15*) resulting in a specific activity for potassium–40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both these elements in milk have been measured extensively and are relatively constant. A brief review of findings over a 3-year period is presented.

A study was made of the PHS Pasteurized Milk Network (PMN) results for calcium content in milk for the period May 1963–March 1966 (*2*). The overall variability of these results was determined, taking into consideration such factors as analytical reproducibility, laboratory bias, sampling, seasonal effects, and geographical differences. The outcome of that analysis was the development of an average value for the PMN and its 2-standard deviation variation, 1.16 ± 0.08 g/liter (~ 7 percent), as an appropriate calcium content in milk for use in general radiological health calculations or discussions. As a result of a parallel study, an average value for the PMN, 1.51 ± 0.21 g/liter (~ 14 percent), for potassium content in milk was developed (*3*).

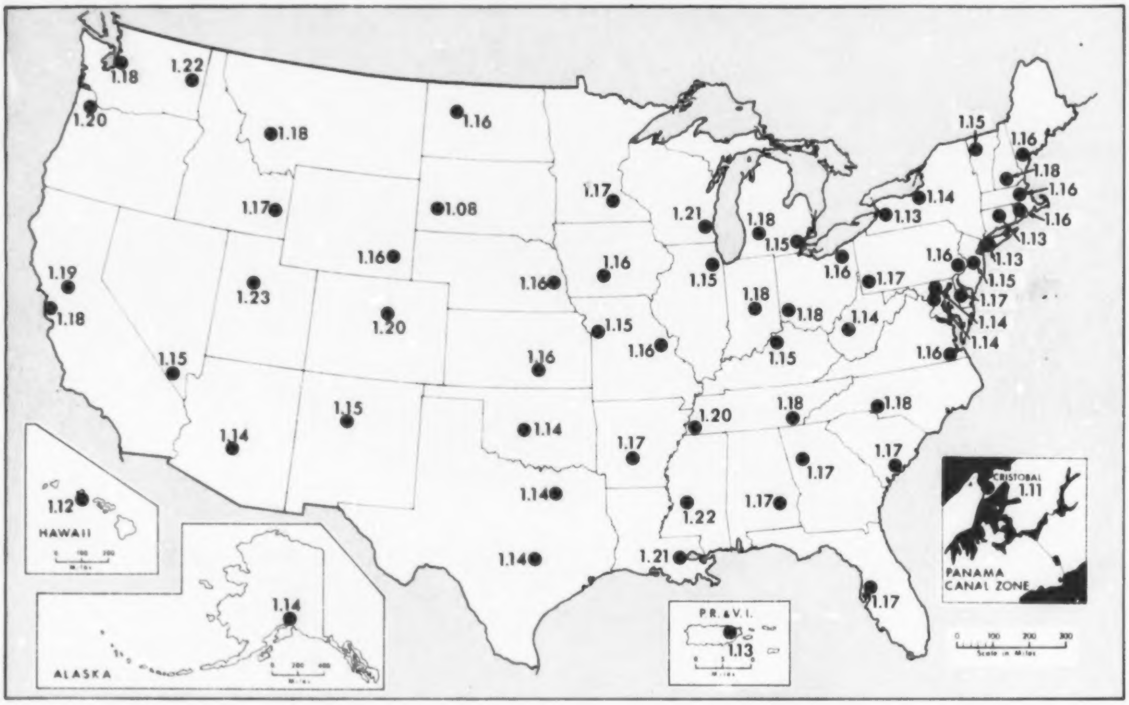
1.18
1.22
1.20
1.18
1.16
1.17
1.08
1.16
1.19
1.18
1.23
1.20
1.16
1.17
1.16
1.15
1.15
1.14
1.15
1.16
1.14
1.14
1.14
1.21
1.15
1.18
1.15
1.16
1.18
1.18
1.15
1.16
1.17
1.14
1.15
1.16
1.18
1.16
1.16
1.13
1.13
1.16
1.13
1.15
1.17
1.14
1.14
1.16
1.20
1.18
1.18
1.17
1.17
1.17
1.22
1.17
1.21
1.17
1.12
HAWAII
1.14
ALASKA
P.R. & V.I.
1.13
CRISTOBAL
1.11
PANAMA CANAL ZONE
Scale in Miles

Figure 2. Average calcium content (g/liter) in pasteurized milk at PMN stations

The content of calcium in milk observed at each of the 63 PMN sampling stations is given in figure 2. The 2-standard deviation value given above for the grand mean of the 63 station averages includes not only the variation among the station averages (4.6 percent), but also includes the average variation observed at a single sampling location from all normal causes (5.5 percent) [2]. The average calcium value for the network and the range of values in figure 2 (1.08 to 1.23 g/liter) are in good agreement with average calcium values and ranges given in dairy references (*4, 5*). A similar presentation for potassium is given in figure 3. The range of potassium content in milk for the PMN stations is 1.45 to 1.66 g/liter. The variation among the 63 station averages was 5.5 percent and the average variation observed at a single sampling location was 13.7 percent [3]. Extension of these findings for the PMN to the State networks considered in this presentation, particularly extension of the 63 individual station averages in figures 2 and 3, allows the average calcium and potassium content and variation to be stated without continuous monitoring for these elements.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the National Center for Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined in the literature (*6*).

---

[2] These two variations are combined as $[(4.6)^2 + (5.5)^2]^{1/2}$ to yield an overall variation of ~ 7 percent (*2*).

[3] These two variations are combined as in footnote 2 to yield an overall variation of ~ 14 percent.

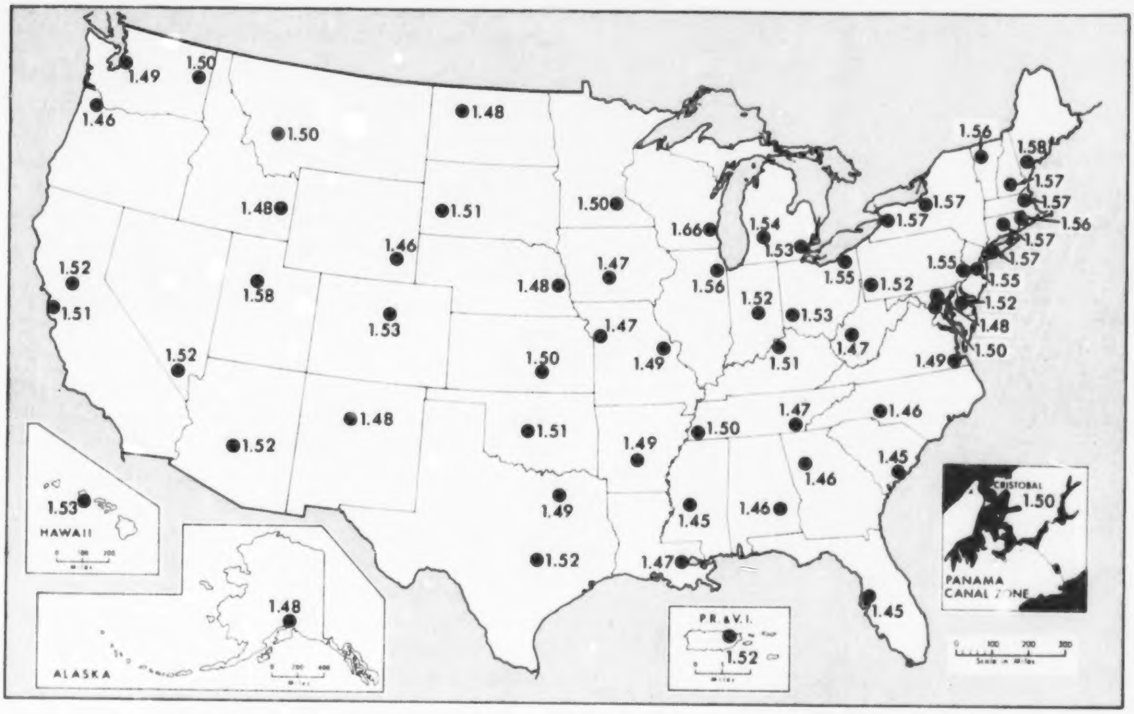
1.49
1.50
1.46
1.50
1.48
1.48
1.51
1.50
1.66
1.54
1.53
1.56
1.58
1.57
1.57
1.56
1.57
1.57
1.57
1.55
1.55
1.52
1.52
1.48
1.50
1.52
1.51
1.58
1.46
1.53
1.48
1.47
1.56
1.52
1.53
1.55
1.52
1.47
1.49
1.51
1.47
1.49
1.52
1.50
1.48
1.51
1.49
1.50
1.47
1.46
1.52
1.49
1.46
1.45
1.53
HAWAII
1.45
1.46
1.47
1.52
1.48
ALASKA
P.R. & V.I.
1.52
1.45
CRISTOBAL
1.50
PANAMA CANAL ZONE
Scale in Miles

Figure 3. Average potassium content (g/liter) in pasteurized milk at PMN stations

The most recent study was conducted in the spring of 1967, with 40 laboratories participating in an experiment on milk samples containing known concentrations of strontium-90, iodine-131, and cesium-137 (7). Of the 19 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 18 participated in the experiment. Discussion of the results of this study is limited to these laboratories. The experiments were conducted at four concentrations of iodine-131, two concentrations of cesium-137, and two concentrations of strontium-90, which represented both high and low levels.

Figures 4 to 6 present the results for the concentrations of strontium-90, iodine-131, and cesium-137 tested which are most representative of current environmental levels.

In figures 4 to 6 a laboratory's results indicated analytical accuracy if the mean value (a measure of bias) and the range value (a measure of internal precision) both fell within the 3-standard deviation limits for the concentration of the particular radionuclide that was measured. Mean and/or range values that fell outside the 3-standard deviation limits reflected analytical errors that should be corrected.

In the majority of cases, the results for the laboratories fell within the 3-standard deviation limits considered appropriate for the various analyses (7). Several results were outside the 3-standard deviation limits and the most deviant of these represented biases from the expected values of 20 to 30 percent. The number of laboratories shown in a specific figure for a particular radionuclide analysis does not total 18 because every laboratory reporting in *Radiological Health Data and Reports* does not routinely perform all of the radionuclide analyses considered. These results were for conditions in the spring of 1967, and therefore do not reflect improvements that may have taken place as a result of the findings of the study. Keeping these possible differences in mind, integration of the data from the various networks can be undertaken without introducing a serious error because of disagreement among the independently obtained data.

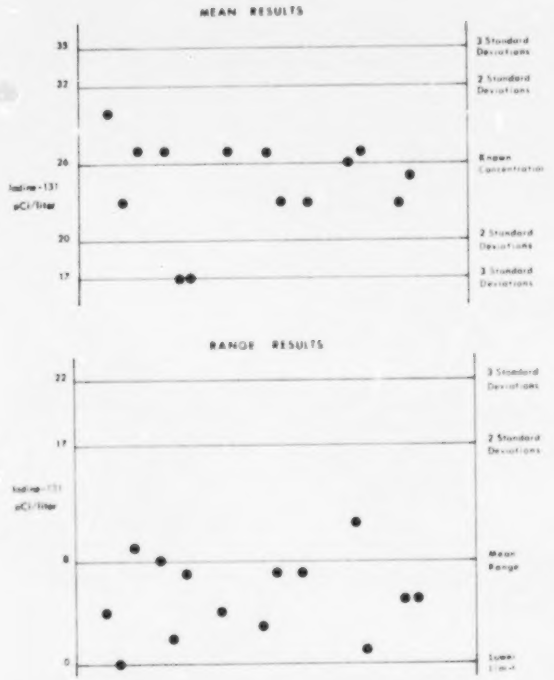

Figure 4. Interlaboratory comparison of iodine-131 measurements in milk at a concentration of 26 pCi/liter

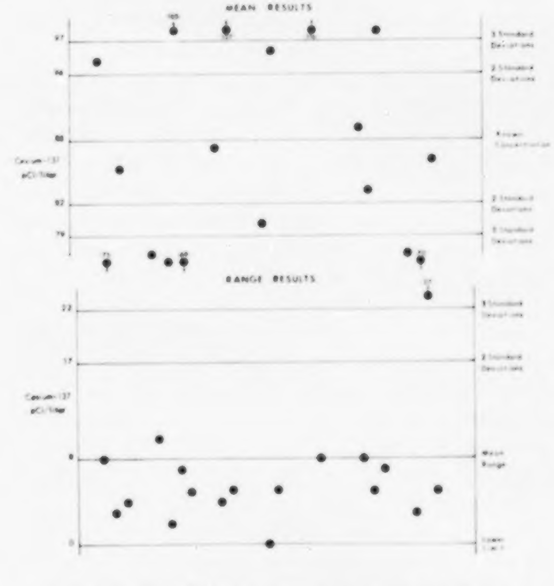

Figure 5. Interlaboratory comparison of cesium-137 measurements in milk at a concentration of 88 pCi/liter

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that regularly report in *Radiological Health Data and Reports* were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion exchange technique and determined by beta-particle counting in low background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy on the whole milk. Each laboratory has its own modifications and refinements of these basic methods. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports.*

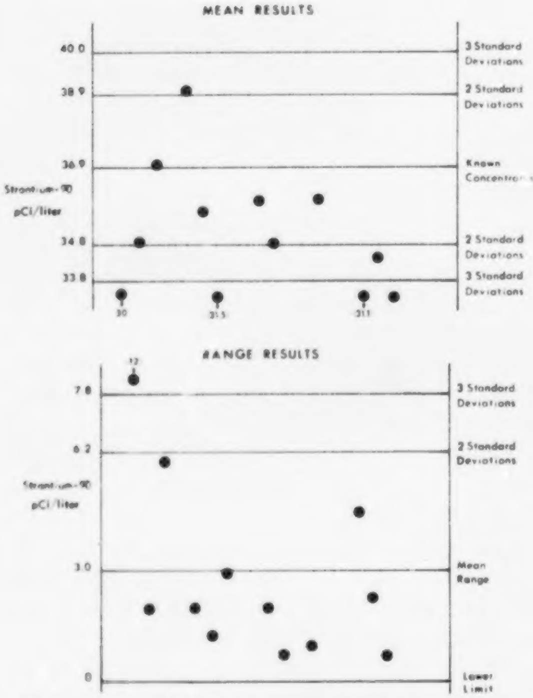

Figure 6. Interlaboratory comparison of strontium-90 measurements in milk at a concentration of 36.9 pCi/liter

A recent article (*8*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. The frequency of collection and analysis not only varies among the networks, but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions will be reflected in the data presentation. While this may appear to complicate comparisons of data, current levels for strontium-90 and cesium-137 are relatively stable over the time periods involved and sampling frequency is not critical. For the case of the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical, and is generally increased at the first measurement or recognition of a new influx of the radionuclide.

Also reflected in the data presentation will be whether raw or pasteurized milk was collected. A recent analysis (*9*) of raw and pasteurized milk samples collected during the period, January 1964–June 1966, indicates that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant. Particular attention was paid to strontium-90 and cesium-137 in that analysis.

The following definition of minimum detectable activity (MDA) is given in National Bureau of Standards Handbook 86 (*10*): ". . . that activity of a radionuclide concerned, which, in a given counting time, increases the reading of an instrument by an amount equal to three times the standard deviation of the background recorded in that time." If one assumes that only random radioactive decay is involved, the following relationship would hold:

$$\text{MDA (pCi/liter)} = \frac{3s}{f} = \frac{3}{f}\sqrt{\frac{B}{t}}$$

where s = standard deviation of background, cpm
B = background counting rate, cpm
t = counting time for routine analysis, minutes
f = sensitivity of the instrument for the procedure employed, cpm/(pCi/liter).

For measurements of beta radioactivity (strontium-89 and strontium-90) the above formula does not consider the interaction of the sample counting variation with the background counting variation. For measurements of gamma radioactivity (iodine-131, cesium-137, barium-140), the above formula can only be based on the energy interval for the gamma ray for which the instrument is calibrated. Therefore, it does not consider contributions to that energy interval from other gamma rays of the same or other radionuclides that occur in other energy intervals in the composite gamma-ray spectrum. This theoretical approach to developing a minimum level for reporting of milk data, therefore, does not adequately reflect all the conditions that determine an actual capability for laboratory measurements.

A second term, the practical reporting level, will now be introduced. The practical reporting level is based on a laboratory's experience in performing the analytical determinations and is a function of its methodology and instrumentation. Each of the networks reported in *Radiological Health Data and Reports* has developed independently such a practical reporting level, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses experiments. Minimum detectable activities, as calculated, and practical reporting levels, as defined, for each of the various networks are presented in table 1. As expected, the minimum detectable activities are lower than the practical reporting levels. Since the practical reporting level reflects additional factors

Table 1. Minimum detectable activities and practical reporting levels for analyzing laboratories

Sampling network	Strontium-89 (pCi/liter)		Strontium-90 (pCi/liter)		Iodine-131 (pCi/liter)		Cesium-137 (pCi/liter)		Barium-140 (pCi/liter)	
	MDA[a]	PRL[b]	MDA	PRL	MDA	PRL	MDA	PRL	MDA	PRL
California	2	3	1	2	5	7	5	7	5	7
Colorado	(c)	(c)	(c)	(c)	15	25	17	25	16	24
Connecticut	0.3	3	0.3	2	7	10	6	10	7	10
Florida	(c)	(c)	1	2	8	10	9	10	8	10
Indiana	.6	1	.6	1	5	10	5	10	5	10
Iowa	(c)	(c)	.5	2	6	10	5	10	(b)	(b)
Michigan	(c)	(c)	1	2	2	14	5	10	2	10
Minnesota	(c)	(c)	.4	1	4	4	4	4	(c)	(c)
New York	2	3	3	3	4	5	12	20	25	100
Oklahoma	(c)	(c)	(c)	(c)	2	3	6	10	(c)	(c)
Oregon	(c)	(c)	2	2	10	15	10	15	10	15
Pennsylvania	(c)	(c)	.9	1	8	10	7	10	18	20
Tennessee	2	5	2	2	8	10	8	10	8	10
Texas	(c)	(c)	.6	2	3	10	3	10	3	5
Washington	(c)	(c)	.3	1	8	10	8	15	8	15
Canada	.3	5	.4	3	3	5	5	10	(c)	(c)
Pasteurized Milk Network	NA	5	NA	2	NA	10	NA	10	NA	10
NERHL[d]	1	NA	1	NA	7	NA	7	NA	7	NA
SERHL[d]	(e)	NA	(e)	NA	(e)	NA	(e)	NA	(e)	NA
SWRHL[d]	1	NA	1	NA	10	NA	10	NA	5	NA
Pan American Health Organization (SERHL)	(e)	5	(e)	2	(e)	10	(e)	10	(e)	10

[a] Minimum detectable activity as calculated by the method described in the text.
[b] Practical reporting level as provided by network.
[c] Analysis not routinely performed by network.
[d] Northeastern Radiological Health Laboratory, Southeastern Radiological Health Laboratory, and Southwestern Radiological Health Laboratory, respectively.
[e] No estimate available.
NA, not applicable.

that are not considered by the minimum detectable activity calculation, such as sample preparation, counting errors not inherent in the minimum detectable activity, and chemical yield variations, it will be used as a more practical basis for reporting data.

In developing a single presentation for the data from the various networks, it would be confusing and impractical to continually refer to a compilation such as table 1 for the various practical reporting levels each time the data are presented. Review of table 1 indicates that while the practical reporting levels vary, the majority of these for any specific radionuclide is within a relatively narrow range. Considering also that these levels are not derived in a consistent manner for all the networks, it would be prudent to simplify this procedure and select an appropriate value for each radionuclide that reflects a meaningful measurement. The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

However, those networks whose practical reporting levels were given as greater than those above will use their reported values in order that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, will be discussed in relation to the revised data presentation format.

Analytical errors of precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks. The precision errors given in table 2

Table 2. Two-standard deviation errors for analytical methodology [a]

Sampling network	Strontium-89		Strontium-90		Iodine-131		Cesium-137		Barium-140	
	Lower levels	Higher levels	Lower levels	Higher levels	Lower levels	Higher levels	Lower levels	Higher levels	Lower levels	Higher levels
California (A)	±3 (<30)	±10% (≥30)	±2 (<20)	±10% (≥20)	±7 (<100)	±10% (≥100)	±7 (<100)	±10% (≥100)	±7 (<100)	±10% (≥100)
Colorado (A)	(b)	(b)	(b)	(b)	±25 (<100)	±10% (≥100)	±25 (<100)	±10% (≥100)	±25 (<100)	±10% (≥100)
Connecticut (C)	(c)	±1 (>20)	(c)	±1 (>20)	(c)	±8 (>100)	(c)	±7 (>100)	(c)	±8 (>100)
Florida (C)	(b)	(b)	±2 (20)	±5% (100)	±10 (100)	2% (1000)	±10 (100)	2% (1000)	±10 (100)	2% (1000)
Indiana (C)	±1 (<20)	±6% (≥20)	±1 (<20)	±6% (≥20)	±5 (<100)	±6% (≥100)	±5 (<100)	±6% (≥100)	±5 (<100)	±6% (≥100)
Iowa (C)	(b)	(b)	±2 (<20)	±10% (≥20)	±6 (<100)	±6% (≥100)	±6 (<100)	±6% (≥100)	(b)	(b)
Michigan (C)	(b)	(b)	±1 (<20)	(c)	±5 (<50)	(c)	±6 (<50)	(c)	±5 (<50)	
Minnesota (C)	(b)	(b)	±1 (<20)	±8% (≥20)	±4 (<50)	±8% (≥50)	±4 (<50)	±8% (≥50)	(b)	(b)
New York (C)	(c)	±10% (≥15)	(c)	±10% (≥30)	(c)	±10% (≥20)	(c)	±10% (≥100)	(c)	±10% (≥250)
Oklahoma (C)	(b)	(b)	(b)	(b)	±2 (<20)	±10% (≥20)	±4 (<55)	±10% (≥55)	(b)	(b)
Oregon (C)	(b)	(b)	±2 (<20)	±10% (≥20)	±10 (<100)	±10% (≥100)	±10 (<100)	10% (≥100)	±10 (<100)	±10% (≥100)
Pennsylvania (C)	(b)	(b)	±2 (<20)	(c)	±10 (20)	(c)	±10 (100)	(c)	±10 (<20)	(c)
Tennessee (C)	±3 (<50)	(c)	±2 (<50)	(c)	±9 (80)	±35 (≅700)	±4 (50)	±18 (400)	±12 (75)	±4 (600)
Texas (C)	±3 (<50)	±10% (≥50)	±2 (<20)	±10% (≥20)	±10 (<100)	±10% (≥100)	±10 (<100)	±10% (≥100)	±10 (<100)	±10% (≥100)
Washington (C)	(c)	(b)	±0.4-1 (1-10)	±1-3 (10-100)	±7 (<100)	±7-9 (100-300)	±7-9 (15-100)	±9-12 (100-300)	±8 (<100)	±8-12 (100-400)
Canada [^{131}I and ^{137}Cs(C) ^{89}Sr and ^{90}Sr(A)]	±5 (<50)	±10% (≥50)	±3 (<50)	±6% (≥50)	±15% (<50)	±10% (≥50)	±4 (<100)	±4% (≥100)	(b)	(b)
Pasteurized Milk Network, NERHL, SERHL, SWRHL [d] (A)	±5 (<50)	±10% (≥50)	±2 (<20)	±10% (≥20)	±10 (<100)	±10% (≥100)	±10 (<100)	±10% (≥100)	±10 (<100)	±10% (≥100)
Pan American Health Organization, SERHL (A)	±5 (<50)	±10% (≥50)	±2 (<20)	±10% (≥20)	±10 (<100)	±10% (≥100)	±10 (<100)	±10% (≥100)	±10 (<100)	±10% (≥100)

[a] All values are in units of pCi/liter, except as indicated as percent (%). The values in parentheses indicate concentration levels in pCi/liter.
(A)—Total analytical error.
(C)—Counting error only.

[b] Analysis not routinely performed by network.

[c] No estimate available.

[d] Northeastern Radiological Health Laboratory, Southeastern Radiological Health Laboratory, Southwestern Radiological Health Laboratory, respectively.

are either the 2-standard deviation counting error or 2-standard deviation total analytical error. Review of table 2 indicates that precision errors for each of the radionuclides would fall in the following ranges.

Radionuclide	Analytical errors of precision, 2-standard deviation
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter
Iodine-131	4–10 pCi/liter for levels <100 pCi/liter; 6–10% for levels ≥100 pCi/liter
Cesium-137	4–10 pCi/liter for levels <100 pCi/liter; 4–10% at levels ≥100 pCi/liter
Barium-140	5–10 pCi/liter at levels <100 pCi/liter; 6–10% for levels ≥100 pCi/liter

For iodine-131, cesium-137 and barium-140 there is one exception to these general ranges which is the 25 pCi/liter value at levels <100 pCi/liter for Colorado. The larger Colorado variation at low levels is a result of the counting time and sample volume presently considered practical by Colorado for evaluation of its milk supplies. This is also reflected in the practical reporting level for that network.

While these errors reflect the precision of the routine measurements, accuracy of the analytical results is best monitored through interlaboratory quality control procedures, such as the one discussed earlier.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance for the use of Federal agencies in the formulation of radiation standards.

Radiation Protection Guides

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risks to the general public that might result from exposures from routine uses of ionizing radiation and the benefits obtained from the activities causing the exposure.

FRC Reports 1 and 2 (*11, 12*) set forth RPG's for specific critical organs (thyroid, bone, bone marrow, and whole body) and intake guidance for strontium-89, strontium-90 and iodine-131. At the same time, the FRC recommended that for radionuclides not specifically considered in the report, Federal agencies should use concentration values which are consistent with recommended RPG's and the general guidance on intake. Therefore, using appropriate FRC recommendations, intake guidance for cesium-137 has been considered also and included in this summary.

The basic guide used for cesium-137 is 0.5 rad/yr[4] as recommended by the FRC for the annual whole body dose to the individual in the population or 0.17 rad/yr for a suitable sample of the exposed population group. Using the dose relationship for cesium-137 given in FRC Report 7 (*14*) and assuming an equilibrium condition for uptake and excretion of cesium-137 in the body, one obtains the equation:

$$D = (11)\frac{I}{W}1.44T_B$$

where, D = the dose in $\frac{\text{rads}}{\text{year}}$

I = the intake in $\frac{\mu\text{Ci}}{\text{day}}$ of cesium-137

---

[4] 0.5 rem/yr is given in FRC Report No. 1 (*11*) for whole body dose. In the case of cesium-137, the rem and the rad can be taken as equivalent units.

W = the body weight in kilograms
11 = dose conversion factor based on the absorption of 0.59 MeV per disintegration
1.44 T_B = the mean biological life in days
where, T_B = the biological half life in days.

Where milk is the vector of interest, the infant is the critical individual in the population. The continuous daily intake corresponding to a whole body dose of 0.17 rad/yr is calculated to be 3,600 pCi/day, assuming the infant weighs 10 kg and the biological half life of cesium-137 is 30 days (*14*).

For the purpose of evaluating population exposure, the daily intake of radionuclides by exposed population groups averaged over a year constitutes an appropriate criterion. However, in order to provide guidance to Federal agencies in developing appropriate control programs, the FRC described a graded approach involving three ranges of transient rates of daily intake as determined by surveillance, applicable to different degrees of action as follows:

Range I —periodic confirmatory surveillance as necessary;
Range II —quantitative surveillance and routine control;
Range III—evaluation and application of additional control measures as necessary.

Based on the above considerations, table 3 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable.

In the absence of specific dietary data one can use milk as the indicator food item for routine surveillance. Assuming a 1 liter per day intake of milk (*13, 14*) one can utilize the graded approach of daily intake on the basis of radionuclide content in milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Protective Action Guides

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a 1 or 2-year

Table 3. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Nuclide	Critical organ	RPG for individual in the general population (rad/yr)	Guidance for suitable samples of exposed population group [a]				
			RPG (rad/yr)	Corresponding continuous daily intake (pCi/day)	Range I (pCi/day)[b]	Range II (pCi/day)[b]	Range III (pCi/day)[b]
Strontium-89	Bone	[c] 1.5	0.5	[d] 2,000	0-200	200-2,000	2,000-20,000
	Bone marrow	[c] 0.5	0.17				
Strontium-90	Bone	[c] 1.5	0.5	[d] 200	0-20	20-200	200-2,000
	Bone marrow	[c] 0.5	0.17				
Iodine-131	Thyroid	1.5	0.5	100	0-10	10-100	100-1,000
Cesium-137 [e]	Whole body	0.5	0.17	3,600	0-360	360-3,600	3,600-36,000

[a] Suitable samples which represent the limiting conditions for this guidance are:
Strontium-89, -90—general population;
Iodine-131—children, 1 year of age;
Cesium-137—infants.

[b] Based on an average intake of 1 liter of milk per day.

[c] A dose of 1.5 rad/yr to the bone is estimated to result in a dose of 0.5 rad/yr to the bone marrow.

[d] For strontium-89 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.

[e] The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

FRC Reports 5 and 7 (*13, 14*) set forth PAG's for the thyroid, bone marrow, and whole body doses from ingestion of foods contaminated with radionuclides following an acute contaminating event. For the case of strontium-89, strontium-90, and cesium-137 contamination, the Council defined three categories of dietary pathways in which action may be required following an acute event as follows:

Category I —transmission of radionuclides to man through the pasture-cow-milk pathway;

Category II —transmission of radionuclides to man through dietary pathways other than the pasture-cow-milk pathway during the first year following an acute contaminating event;

Category III—long-term transmission of strontium-90 and cesium-137 through soil into plants in the years following a contaminating event.

This discussion is restricted to a consideration of Category I.

In the case of iodine-131 contamination, the maximum concentration of iodine-131 observed in milk which may occur 2 to 4 days following an acute incident, can be used to project doses for comparison to the PAG for the thyroid. For strontium-89, strontium-90 and cesium-137, the total dose to the critical organ resulting from contributions of all three of these radionuclides must be considered to determine whether the projected dose will exceed the recommended PAG for the organ of interest (bone marrow or whole body).

Based on the above conditions, table 4 represents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. Also given in table 4 are milk concentrations for each of the radionuclides considered, in the absence of the others, which if attained after an acute incident would result in doses equivalent to the appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for an acute deposition and the pasture-cow-milk-man pathway and from an estimate of the intake prior to reaching the maximum concentration (*13*). Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples.

Table 4. Protective Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclides	Critical organ	PAG for individuals in general population (rads)	Category I (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Concentration at maximum in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-89	Bone marrow	10 in first yr; total dose not to exceed 15 [a, b]	3 in first yr; total dose not to exceed 5 [a, b]	[c] 1,110,000
Strontium-90	Bone marrow			[c] 51,000
Cesium-137	Whole body			[c] 720,000
Iodine-131	Thyroid	30	10	[d] 70,000

[a] The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.

[b] Total dose from strontium-89 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.

[c] These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.

[d] This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered.

Data reporting format

Commencing with the present issue of *Radiological Health Data and Reports*, milk surveillance data are presented in a revised format integrating the various milk surveillance networks. Repetitive descriptions of the individual network activities and long-term milk concentration trends will be discontinued, however, the factors necessary for interpreting current data will be appropriately summarized.

Table 5 presents this revised format. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. (The relationships between the PMN

19.7

Table 5. Concentrations of radionuclides in milk for August 1968 and 12-month period September 1967 through August 1968

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
United States:								
Ala:	Montgomery[c]	P	10	9	0(5)	0	16(5)	14
Alaska:	Palmer[c]	P	NA	5	0(3)	0	22(3)	14
Ariz:	Phoenix[c]	P	NA	1	0(5)	0	8(5)	2
Ark:	Little Rock[c]	P	24	21	0(4)	0	18(4)	19
Calif:	Sacramento[c]	P	0	2	0(5)	0	3(5)	6
	San Francisco[c]	P	0	1	0(5)	0	0(5)	5
	Del Norte	P	23	18	0	0	34	21
	Fresno	P	0	0	0	0	22	5
	Humboldt	P	4	4	0	0	23	10
	Los Angeles	P	0	0	0	0	17	6
	Mendocino	P	3	2	0	0	19	4
	Sacramento	P	3	2	0	0	16	6
	San Diego	P	0	0	0	0	20	2
	Santa Clara	P	0	4	0	0	14	6
	Shasta	P	4	3	0	0	0	2
	Sonoma	P	3	2	0	0	21	6
Colo:	Denver[c]	P	4	4	0(5)	0	12(5)	7
	Western	R	—	—	(e)	(e)	(e)	(e)
	Northeast	R	—	—	e(3)	(e)	(e)	(e)
	Eastern	R	—	—	NS	(e)	NS	(e)
	Southeast	R	—	—	NS	(e)	NS	(e)
	South Central	R	—	—	NS	(e)	NS	(e)
Conn:	Hartford[c]	P	13	10	0(5)	0	16(5)	12
	Central	R	9	8	0(5)	0	13(5)	9
Del:	Wilmington[c]	P	10	11	0(5)	0	8(5)	8
D.C.:	Washington[c]	P	9	10	0(5)	0	10(5)	7
Fla:	Tampa[c]	P	9	8	0(4)	0	71(4)	66
	West	R	9	17	14	3	28	25
	North	R	NS	17	NS	3	NS	26
	Northeast	R	9	9	0	2	124	91
	Central	R	7	10	0	8	81	108
	Tampa Bay area	R	7	8	0	0	77	76
	Southeast	R	8	9	0	2	111	95
Ga:	Atlanta	P	19	15	0(4)	0	21(4)	20
Hawaii:	Honolulu[c]	P	5	3	0(4)	1	0(4)	4
Idaho:	Idaho Falls[c]	P	8	6	0(4)	0	8(4)	8
Ill:	Chicago[c]	P	10	9	0(4)	0	11(4)	10
Ind:	Indianapolis[c]	P	8	7	0(4)	0	3(4)	7
	Northeast	P	12	9	0	0	0	5
	Southeast	P	14	10	0	0	0	10
	Central	P	7	8	0(4)	0	0(4)	6
	Southwest	P	9	10	0	2	15	12
	Northwest	P	10	9	0(4)	0	15(4)	8
Iowa:	Des Moines[c]	P	4	7	0(4)	0	13(4)	7
	Iowa City	P	8(3)	7	0(3)	0	15(4)	2
	Des Moines	P	5(2)	7	0(2)	0	9(2)	2
	Spencer	P	8	7	0	0	0	8
	Charles City	P	NS		NS		NS	
Kans:	Wichita[c]	P	4	9	0(4)	0	1(4)	5
Ky:	Louisville[c]	P	14	12	0(4)	0	1(4)	5
La:	New Orleans[c]	P	18	21	0(5)	0	25(5)	24
Maine:	Portland[c]	P	14	12	0(4)	0	32(4)	29
Md:	Baltimore[c]	P	13	10	0(4)	0	13(4)	6
Mass:	Boston[c]	P	16	13	0(4)	0	30(4)	25
Mich:	Detroit[c]	P	9	9	0(4)	0	9(4)	11
	Grand Rapids[c]	P	11	10	0(4)	0	13(4)	14
	Bay City	P	4	4	e(2)	(e)	7(2)	5
	Charlevoix	P	NS	5	NS	(e)	NS	6
	Detroit	P	5	5	e(4)	(e)	3(4)	5
	Grand Rapids	P	NA	5	e(4)	(e)	12(4)	7
	Lansing	P	5	4	e(2)	(e)	0(2)	2
	Marquette	P	9	7	e(2)	(e)	32(2)	21
	Monroe	P	0	4	e(2)	(e)	0(2)	2
Minn:	Minneapolis[c]	P	14	11	0(4)	0	11(4)	12
	Bemidji	P	20	15	0	0	38	22
	Mankato	P	5	6	0	0	0	0
	Rochester	P	10	8	0	0	12	0
	Duluth	P	25	19	0	0	33	28
	Worthington	P	5	6	0	0	0	0
	Minneapolis	P	14	12	0	0	17	12
	Fergus Falls	P	12	9	0	0	10	11
	Little Falls	P	10	9	0	0	19	13
Miss:	Jackson[c]	P	13	17	0(4)	0	16(4)	15
Mo:	Kansas[c]	P	10	8	0(5)	0	9(5)	5
	St. Louis[c]	P	7	9	0(5)	0	8(5)	8
Mont:	Helena	P	6	5	0(4)	0	10(4)	8
Nebr:	Omaha[c]	P	6	7	0(5)	0	10(5)	5
Nev:	Las Vegas[c]	P	0	1	0(4)	0	1(4)	4
N.H.:	Manchester[c]	P	18	14	0(4)	0	55(4)	36
N.J.:	Trenton[c]	P	11	10	0(4)	0	10(4)	10
N.Mex:	Albuquerque[c]	P	4	2	0(4)	0	0(4)	2

See footnotes at end of table.

198

Table 5. Concentrations of radionuclides in milk for August 1968 and 12-month period September 1967 through August 1968—continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
N.Y.:	Buffalo[c]	P	9 (5)	9	0 (5)	0	10 (5)	14
	New York City[c]	P	14	10	0 (4)	0	15 (4)	13
	Syracuse[c]	P	8	7	0 (4)	0	6 (4)	7
	Albany	P	10 (5)	8	0 (4)	1	[e] (2)	12
	Buffalo	P	8	4	0	2	(e)	14
	Massena	P	12	10	0	1	(e)	22
	Newburg	P	(e)	9	0	15	(e)	1
	New York City	P	11 (2)	10	0 (2)	1	29 (2)	23
	Syracuse	P	NS	10	NS	2	NS	15
N.C.:	Charlotte[c]	P	16	15	0 (4)	1	15 (4)	12
N. Dak:	Minot[c]	P	11	11	0 (4)	0	15 (4)	12
Ohio:	Cincinnati[c]	P	8	9	3 (4)	0	7 (4)	7
	Cleveland[c]	P	13	10	0 (5)	0	6 (5)	8
Okla:	Oklahoma City[c]	P	10	10	0 (4)	0	1 (4)	4
	Oklahoma City	P	NS	NS	NS	NS	NS	NS
	Enid	P	NS	NS	NS	NS	NS	NS
	Tulsa	P	NS	NS	NS	NS	NS	NS
	Lawton	P	NS	NS	NS	NS	NS	NS
	Ardmore	P	NS	NS	NS	NS	NS	NS
Ore:	Portland[c]	P	6	7	0 (5)	0	13 (5)	15
	Baker	P	NA	6	(d)	(d)	(d)	4
	Coos Bay	P	NA	12	(d)	(d)	(d)	15
	Eugene	P	NA	4	(d)	(d)	35	12
	Medford	P	NA	4	(d)	(d)	(d)	9
Ore:	Portland composite	P	NA	8	(d)	(d)	19 (5)	11
	Portland local	P	NA	7	(d)	(d)	16 (5)	14
	Redmond	P	NA	5	(d)	(d)	(d)	9
	Tillamook	R	NA	10	(d)	(d)	30	27
Pa:	Philadelphia[c]	P	12	9	0 (5)	0	7 (5)	9
	Pittsburgh[c]	P	12	12	0 (4)	0	11 (4)	14
	Dauphin	P	13	8	0	0	30	15
	Erie	P	10 (2)	12	0	0	47	22
	Philadelphia	P	11	10	0	0	27	16
	Pittsburgh	P	17	13	0	0	13	15
R.I.:	Providence[c]	P	13	11	0 (4)	0	27 (4)	18
S.C.:	Charleston[c]	P	16	15	0 (4)	0	29 (4)	27
S. Dak:	Rapid City[c]	P	11	10	0 (4)	0	9 (4)	10
Tenn:	Chattanooga[c]	P	13	14	0 (4)	0	14 (4)	13
	Memphis[c]	P	12	12	0 (5)	0	3 (5)	5
	Chattanooga	P	12	14	0 (4)	0	12 (4)	18
	Clinton	P	14	14	0 (2)	4	16 (2)	22
	Knoxville	P	12	13	13	3	0	24
	Nashville[d]	P	NS	8	NS	0	NS	20
Tex:	Austin[c]	P	3	4	0 (3)	0	0 (3)	2
	Dallas[c]	P	7	7	0 (4)	0	3 (4)	6
	Amarillo	R	NA	5	NA	0	NA	0
	Corpus Christi	R	NA	4	NA	0	NA	0
	El Paso	R	NA	2	NA	0	NA	0
	Fort Worth	R	NA	6	NA	0	NA	0
	Harlington	R	NA	3	NA	0	NA	0
	Houston	R	NA	11	NA	0	NA	8
	Lubbock	R	NA	4	NA	0	NA	0
	Midland	R	NA	4	NA	0	NA	0
	San Antonio	R	NA	3	NA	0	NA	0
	Texarkana	R	NA	11	NA	0	NA	8
	Uvalde	R	NA	2	NA	0	NA	0
	Wichita Falls	R	NA	10	NA	0	NA	0
Utah:	Salt Lake City[c]	P	4	5	0 (4)	0	8 (4)	11
Vt:	Burlington[c]	P	11	11	0 (4)	0	6 (4)	11
Va:	Norfolk[c]	P	14	11	0 (5)	0	6 (5)	8
Wash:	Seattle[c]	P	12	9	0 (5)	0	26 (5)	21
	Spokane[c]	P	5	7	0 (4)	0	4 (4)	11
	Benton County	R	NS	0	NS	0	NS	(d)
	Deer Park	R	4	4	0	0	(d)	(d)
	Elma	R	4	5	0	0	26	23
	Franklin County	R	0	0	0	0	(d)	(d)
	Moses Lake	R	0	0	0	0	(d)	(d)
	Pierce County	R	5	3	0	0	29	7
	Sandpoint, Idaho	R	7	7	0	0	29	23
	Skagit County	R	7	4	0	0	(d)	15
W. Va:	Charleston[c]	P	12	12	0 (2)	0	8 (2)	4
Wisc:	Milwaukee[c]	P	8 (4)	8	0 (4)	0	8 (4)	11
Wyo:	Laramie[c]	P	4	4	0 (4)	0	3 (4)	7
Canada:								
Alberta:	Calgary	R	10	9	—	—	20	18
	Edmonton	R	7	8	—	—	22	22
British Columbia:	Vancouver	R	12	15	—	—	55	50
Manitoba:	Winnipeg	R	7	8	—	—	23	24
New Brunswick:	Fredericton	R	15	15	—	—	30	25
Newfoundland:	St. Johns	R	30	21	—	—	74	41
Nova Scotia:	Halifax	R	11	13	—	—	26	25
Ontario:	Ft. William	R	17	15	—	—	39	28
	Ottawa	R	8	9	—	—	21	19

See footnotes at end of table.

Table 5. Concentrations of radionuclides in milk for August 1968 and 12-month period September 1967 through August 1968—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average	Monthly average [b]	12-month average
Canada:—Cont.								
	Sault Ste. Marie	R	16	15	—	—	34	27
	Toronto	R	5	5	—	—	12	15
	Windsor	R	5	9	—	—	9	13
Quebec:	Montreal	R	7	10	—	—	22	20
	Quebec	R	13	13	—	—	32	28
Saskatchewan:	Regina	R	11	8	—	—	18	15
	Saskatoon	R	10	9	—	—	18	17
Central and South America:								
Columbia:	Bogota	P	3	0	0	0	0	2
Chile:	Santiago	P	0	0	0	0	0	0
Ecuador:	Guayaquil	P	0	0	0	0	0	2
Jamaica:	Mandeville	P	6	6	0	0	75	135
Venezuela:	Caracas	P	3	1	0	0	0	0
Canal Zone:	Cristobal [c]	P	3	1	7(4)	1	11(4)	9
Puerto Rico:	San Juan [c]	P	6	5	0(3)	0	12(3)	11

[a] P, pasteurized milk. R, raw milk.

[b] When an *individual sampling result* was equal to or less than the practical reporting level, a value of "0" was used for averaging. *Monthly averages* less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] U.S. PHS Pasteurized Milk Network Station. All other sampling locations are part of the State or national network.

[d] The practical reporting levels for these networks differ from the general ones given in the text. Individual results for these networks were equal to or less than the following practical reporting levels:

^{131}I: Colorado —25 pCi/liter
Michigan—14 pCi/liter
Oregon —15 pCi/liter

^{137}Cs: Colorado —25 pCi/liter
Oregon —15 pCi/liter
New York —20 pCi/liter
Washington—15 pCi/liter

^{90}Sr: New York—3 pCi/liter

NA no radionuclide analysis for the month.
NS, no sample collected for the month.
—Radionuclide analysis not routinely performed.

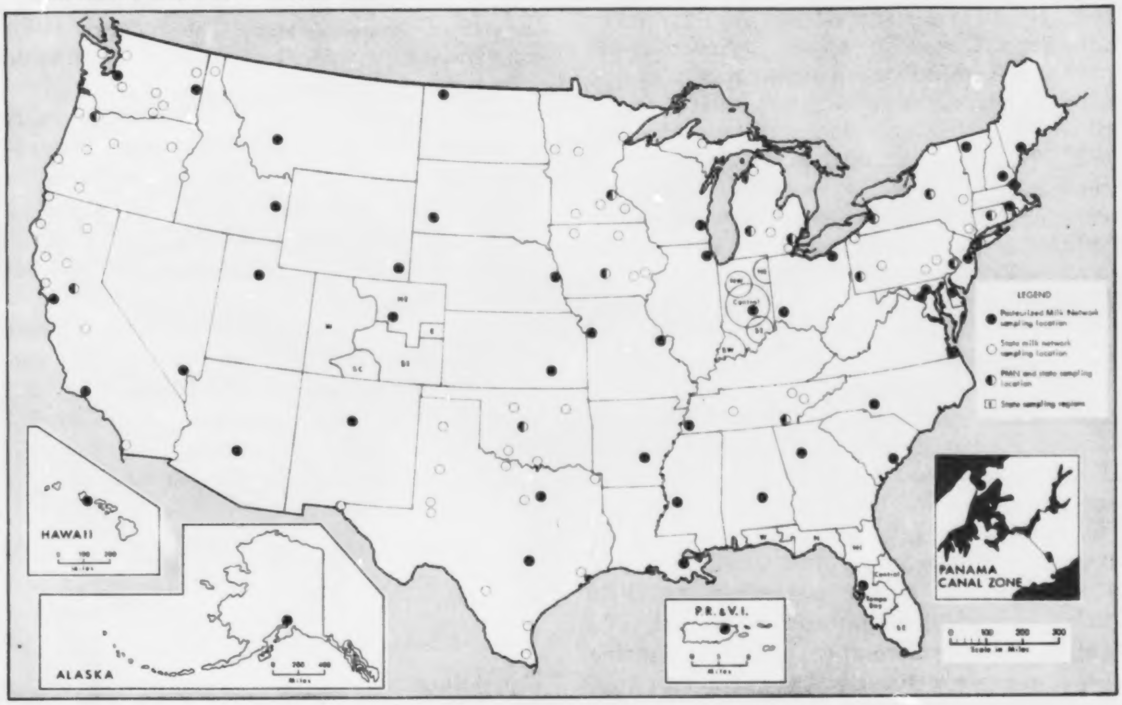
LEGEND
● Pasteurized Milk Network sampling location
○ State milk network sampling location
◐ PMN and state sampling location
State sampling region
HAWAII
ALASKA
P.R. & V.I.
PANAMA CANAL ZONE
Scale in Miles

Figure 7. State and PHS milk sampling stations in the United States

stations and State stations are shown in figure 7.) The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of 0 is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level. This procedure is required in order to have numerical monthly concentration estimates that reflect all samples with detectable radioactivity, particularly when average annual intakes are developed.

If the occasion rises when an influx of new contamination occurs, particularly in the case of iodine–131, where sampling frequencies increase and/or the range of radionuclide concentration values for a month are significantly wider than the normal steady-state conditions, a column will be added after the appropriate monthly averages reflecting the maximum value for that month. It is the transient maximum value of radionuclide concentrations resulting from an acute contaminating event to which the maximum concentration given in table 4 [derived from the FRC protective action guides (PAG)] can be compared. However, any protective action based on these concentrations being reached will take place immediately on the observance of the high concentrations. Should such cases occur, a more complete discussion of the events would be required and will be provided.

The second column under each of the reported radionuclide gives the 12-month average for the station as calculated from preceding 12-month averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides (RPG's) apply (the control and regulation of normal peacetime uses of nuclear technology), the 12-month average serves as a basis for comparison.

Discussion of current data

In table 5, surveillance results are given for strontium–90, iodine–131, and cesium–137 for August 1968 and the 12-month period, September 1967–August 1968. Except where noted the monthly average represents a single sample for the sampling station. Strontium–89 and barium–140 data have been omitted from table 5, since levels at the great majority of the stations for August 1968 were below the respective practical reporting levels, however, the exceptions are shown in table 6.

Iodine–131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (table 3), levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine–131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium–90 monthly averages ranged from 0 to 25 pCi/liter in the United States for the month of August 1968. The maximum 12-month average was 21 pCi/liter (Little Rock, Ark.), representing 9.5 percent of the Federal Radiation Council radiation protection guide (table 3). Cesium–137 monthly averages ranged from 0 to 124 pCi/liter in the United States for the month of August 1968. The maximum 12-month average was 108 pCi/liter (Central Florida) representing 3.3 percent of the value calculated in this report using the recommendations given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium–137 levels that have been observed in Florida (*16*) and Jamaica. Iodine–131 monthly averages were generally below practical reporting levels with the following exceptions:

Fla: West (State)	14 pCi/liter
Ohio: Cincinnati (PMN)	3 pCi/liter (4 samples)
Tenn: Knoxville (State)	13 pCi/liter
Canal Zone: Cristobal (PMN)	7 pCi/liter (4 samples)

Table 6. Reported strontium-89 and barium-140 concentrations in milk

Strontium-89		Barium-140			
Sampling location	Monthly average (pCi/liter)	Sampling location	Monthly average (pCi/liter)	Sampling location	Monthly average (pCi/liter)
Iowa: Des Moines (PMN)	6	Ariz: Phoenix (PMN)	3(5)[a]	Kans: Wichita (PMN)	2(4)
Columbia: Bogata (PAHO)	10	Calif: Del Norte (State)	14	Minn: Minneapolis (PMN)	2(4)
Ecuador: Guayaquil (PAHO)	10	Fresno (State)	18	Mo: St. Louis (PMN)	1(5)
Santiago: Chile (PAHO)	15	Humboldt (State)	17	Mont: Helena (PMN)	6(4)
Venezuela: Caracas (PAHO)	15	Los Angeles (State)	14	Nebr: Omaha (PMN)	2(5)
		Mendocino (State)	21	Nev: Las Vegas (PMN)	2(4)
		San Diego (State)	17	N. Mex: Albuquerque (PMN)	3(4)
		Santa Clara (State)	15	S. Dak: Rapid City (PMN)	3(4)
		Sonoma (State)	23	Wash: Seattle (PMN)	6(5)
		Fla: West (State)	14	Spokane (PMN)	2(4)
		Southeast (State)	11	Canal Zone: Cristobal (PMN)	3(4)
		Iowa: Des Moines (PMN)	2(4)		

[a] Number of samples in parentheses.

REFERENCES

(1) CAMPBELL, J. E., G. K. MURTHY, A. S. GOLDIN, H. B. ROBINSON, C. P. STRAUB, F. J. WEBER and K. H. LEWIS. The occurrence of strontium-90, iodine-131 and other radionuclides in milk, May 1957 through April 1958. American J Public Health 49:225 (February 1959).

(2) ROSENSTEIN, M. Derivation of a general calcium content in milk for radiological health purposes. Radiological Health Standards and Intelligence Report SIB-6701, National Center for Radiological Health (September 1967).

(3) OATES, W. and M. ROSENSTEIN. Derivation of a general potassium content in milk for radiological health purposes. Radiological Health Standards and Intelligence Report SIB-6801. National Center for Radiological Health (in preparation).

(4) ROADHOUSE, C. G. and R. J. HENDERSON. Market Milk Industry. McGraw-Hill, New York-London (1950) p. 622.

(5) HARREL, C. G. and R. J. THELEN. Conversion Factors and Technical Data for the Food Industry. Burgess Publishing Company, Minneapolis, Minn. (1959) p. 338.

(6) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(7) KAUFFMAN, P. and F. KNOWLES. Interlaboratory study of iodine-131, cesium-137 and strontium-90 measurements in milk, March-April 1967. Technical Experiment M-1-67, Analytical Quality Control Service, National Center for Radiological Health (August 1967).

(8) NEILL, R. H. and D. R. SNAVELY. State Health Department sampling criteria for surveillance of radioactivity in milk. Radiol Health Data Rep 8:621-627 (November 1967).

(9) ROBINSON, P. B. A Comparison of Results Between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 8:475-488 (September 1968).

(10) U.S. DEPARTMENT OF COMMERCE. Recommendations of the International Commission on Radiological Units and Measurements, NBS Handbook No. 86 (November 1963) p. 26.

(11) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 13, 1960).

(12) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

(13) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 5. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1964).

(14) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, protective action guides for strontium-89, strontium-90 and cesium 137, Report No. 7. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1965).

(15) Chart of the Nuclides—Ninth Edition revised to July 1966. Knolls Atomic Power Laboratory (November 1966).

(16) PORTER, C. R., C. R. PHILLIPS, M. W. CARTER, and B. KAHN. The Cause of Relatively High Cesium-137 Concentrations in Tampa, Florida, Milk. Radioecological Concentration Processes, Proceedings of an International Symposium held in Stockholm, April 25-29, 1966. Pergamon Press, New York, N.Y. (1966) pp. 95-101.

Acknowledgment

Appreciation is expressed to the personnel of the following health agencies who provided the details on their milk surveillance networks:

Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiological Health Section
Division of Air, Occupational and Radiation Hygiene
Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Division of Radiological Health
Bureau of Preventable Diseases
Florida State Board of Health

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiation and Occupational Health Section
Division of Environmental Sanitation
State of Minnesota Department of Health

Bureau of Radiological Health
Division of Environmental Health Services
New York Department of Health

Division of Occupational and Radiological Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Health

Bureau of Environmental Health Services
Division of Radiological Health
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows.

Program	Period reported	Last presented
California Diet Study	July-October 1967	May 1968
Connecticut Standard Diet	January–June 1968	November 1968
Institutional Diet, PHS	January-March 1968	October 1968
Tri-City Diet, HASL	April-December 1967	June 1968

204

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

Water sampling program	Period reported	Last presented
California	July–December 1967	November 1968
Coast Guard	January–December 1967	November 1968
Florida	1965–1966	July 1968
Minnesota	July–December 1967	October 1968
New York	June–December 1967	October 1968
Radiostrontium in Tap Water, HASL	January–June 1967	April 1968
Washington	July 1966–June 1967	August 1968

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

---

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Gross Radioactivity in Surface Waters of the United States, June 1968

Division of Pollution Surveillance
Federal Water Pollution Control Administration
Department of the Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as part of the Water Pollution Surveillance System currently operated by the Federal Water Pollution Control Administration. Table 1 presents the current preliminary results of the alpha and beta radioanalyses. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium-90 results are reported semiannually. The stations on each river are arranged in the table according to their distance from the headwaters. Figure 1 indicates the average total beta radioactivity in suspended-plus dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the November 1968 issue of *Radiological Health Data and Reports.*

Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data for comment. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. A dis-

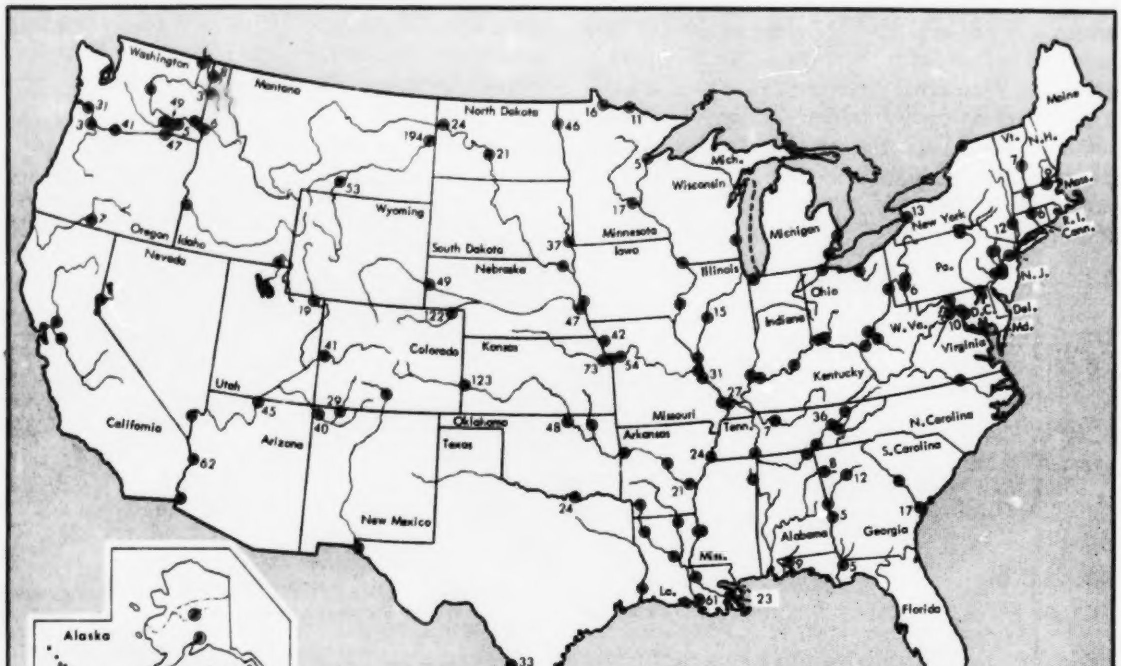
Washington
Montana
North Dakota
Maine
Vt.
N.H.
Mass.
R.I.
Conn.
New York
Wisconsin
Mich.
Michigan
Minnesota
Iowa
Illinois
Ohio
Indiana
Pa.
N.J.
Del.
Md.
D.C.
W. Va.
Virginia
Kentucky
Tenn.
N. Carolina
S. Carolina
Georgia
Alabama
Miss.
La.
Florida
Missouri
Arkansas
Oklahoma
Texas
Kansas
Nebraska
South Dakota
Wyoming
Colorado
New Mexico
Utah
Arizona
Nevada
California
Oregon
Idaho
Alaska
Scale in Miles
31
3
41
49
5
47
3
6
7
53
194
24
21
46
16
11
5
17
37
49
47
19
22
41
123
45
29
40
62
42
73
54
15
31
27
48
24
21
24
7
36
8
12
5
17
9
5
61
23
33
13
12
6
10
7
9
8

Figure 1. Sampling locations and associated total beta radioactivity (pCi/liter) in surface waters, June 1968

206

cussion of gross radioactivity per gram of solids for all stations of the Water Pollution Surveillance System for 1961 through 1965 has been presented (*7*). Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

The following stations showed alpha radioactivity on suspended or dissolved solids greater than 15 pCi/liter:

Arkansas River; Coolidge, Kans.
Big Horn River; Hardin, Mont.
Kansas River; Desoto, Kans.
North Platte River; Henry, Nebr.
South Platte River; Julesburg, Colo.
Yellowstone River; Sidney Mont.

Sidney, Mont. on the Yellowstone River also showed beta radioactivity on suspended solids above 150 pCi/liter.

Table 1. Radioactivity in raw surface water, June 1968

Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:						
Cedar Hill, N. Mex	4	0	4	23	6	29
Apalachicola River:						
Chattahoochee, Fla	[illegible]	0	1	1	4	5
Arkansas River:						
Coolidge, Kans	[illegible]	43	61	59	64	123
Ponca City, Okla	5	2	7	28	20	48
Pendleton Ferry, Ark	2	0	2	10	11	21
Atchafalaya River:						
Morgan City, La	10	1	11	50	11	61
Big Horn River:						
Hardin, Mont	16	6	22	36	17	53
Big Sioux River:						
Sioux Falls, S. Dak	2	1	3	8	29	37
Chattahoochee River:						
Atlanta, Ga	1	0	1	1	11	12
Columbus, Ga	1	0	1	2	3	5
Clearwater River:						
Lewiston, Idaho	< 1	< 1	< 1	3	3	6
Clinch River:						
Kingston, Tenn [a]	0	0	0	2	34	36
Colorado River:						
Loma, Colo	6	4	10	12	29	41
Page, Ariz	0	8	8	2	43	45
Parker Dam, Calif-Ariz	0	9	9	3	59	62
Columbia River:						
Pasco, Wash [a]	< 1	1	1	19	30	49
McNary Dam, Ore	0	1	1	19	28	47
Bonneville, Ore	0	1	1	7	34	41
Clatskanie, Ore	1	1	2	16	15	31
Connecticut River:						
Wilder, Vt	0	0	0	2	5	7
Enfield Dam, Conn	0	1	1	2	4	6
Coosa River:						
Rome, Ga	< 1	1	1	3	5	8
Cumberland River:						
Cheatham Lock, Tenn	0	1	1	2	5	7
Escambia River:						
Century, Fla	1	1	2	4	5	9
Great Lakes:						
Duluth, Minn	0	0	0	1	4	5
Detroit, Mich	0	0	0	2	11	13
Green River:						
Dutch John, Utah	0	6	6	1	18	19
Hudson River:						
Poughkeepsie, N.Y	0	0	0	7	5	12
Illinois River:						
Peoria, Ill	1	2	3	5	10	15
Kansas River:						
DeSoto, Kans	25	4	29	51	22	73
Klamath River:						
Keno, Ore	1	1	2	1	6	7
Merrimack River:						
Lowell, Mass	0	0	0	3	6	9
Mississippi River:						
St. Paul, Minn	0	2	2	4	13	17
E. St. Louis, Ill	4	1	5	22	9	31
W. Memphis, Ark	5	0	5	16	8	24
New Orleans, La	5	1	6	15	8	23
Missouri River:						
Williston, N. Dak	3	5	8	12	12	24
Bismarck, N. Dak	1	4	5	1	20	21
St. Joseph, Mo	9	8	17	25	17	42
Missouri City, Mo	10	4	14	20	34	54
Monongahela River:						
Pittsburgh, Pa	2	0	2	2	4	6
North Platte River:						
Henry, Nebr	3	19	22	11	38	49
Ohio River:						
Cairo, Ill	6	1	7	20	7	27
Pend Oreille River:						
Albeni Falls Dam, Idaho	< 1	< 1	< 1	1	7	8
Platte River:						
Plattsmouth, Nebr	4	7	11	18	29	47
Potomac River:						
Washington, D.C	1	0	1	7	3	10
Rainy River:						
International Falls, Minn	0	0	0	2	9	11
Baudette, Minn	0	1	1	4	12	16
Red River, North:						
Grand Forks, N. Dak	4	3	7	21	25	46
Red River, South:						
Denison, Tex	0	2	2	2	22	24
Rio Grande:						
Laredo, Tex	1	4	5	5	28	33
San Juan River:						
Shiprock, N. Mex	10	2	12	30	10	40
Savannah River:						
Port Wentworth, Ga. [a]	1	< 1	1	5	12	17
Shenandoah River:						
Berryville, Va	0	1	1	0	3	3
Snake River:						
Ice Harbor Dam, Wash	0	0	0	1	4	5
South Platte River:						
Julesburg, Colo	5	40	45	22	100	122
Spokane River:						
Post Falls Dam, Idaho	0	0	0	2	1	3
Willamette River:						
Portland, Ore	0	0	0	1	2	3
Yellowstone River:						
Sidney, Mont	28	1	29	165	29	194
Maximum	28	43	61	165	100	194
Minimum	0	0	0	1	1	3

[a] Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides.

REFERENCES

(*1*) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. National water quality network annual compilation of data, PHS Publication No. 663, 1958 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*2*) *Ibid.*, 1959 Edition.

(*3*) *Ibid.*, 1960 Edition.

(*4*) *Ibid.*, 1961 Edition.

(*5*) *Ibid.*, 1962 Edition.

(*6*) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. Water pollution surveillance system, annual compilation of data, PHS Publication No. 663 (Revised), 1963 Edition. Superintedent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*7*) JULIAN, E. C. Gross radioactivity of the solids in selected surface waters of the United States, 1961–1965. Radiol Health Data Rep 9:1–15 (January 1968).

Radioactivity in Surface Waters of the Colorado River Basin, 1967

Colorado River Basin Water Quality Control Project
Federal Water Pollution Control Administration
Department of the Interior

The Radium Monitoring Network is a surface water surveillance system currently consisting of 20 sampling stations located throughout the Colorado River basin (figure 1). During initial stages of the surveillance program, the system consisted of 27 sampling stations. The purpose of this network is to provide a continuous assay of basin river water radioactivity resulting primarily from uranium mining and milling industry waste discharges. Recently, the types of sample analyses were expanded from radium–226 and uranium to include gross alpha radioactivity, gross beta radioactivity, thorium alpha radioactivity, lead–210 and strontium–90, to provide a more comprehensive picture of contributions of radiological contaminants to surface waters of the Colorado River Basin by the uranium industry and by fallout from nuclear testing. The network was established following a 1957 conference on uranium milling wastes, attended by representatives of the States of Arizona, Colorado, New Mexico, and Utah, and the U.S. Public Health Service. A summary of data collected through 1966 was published in May 1968 (*1*).

Sampling procedures

Depending on individual station parameters, Radium Monitoring Network (RMN) samples are collected as either automatic or grab samples. Grab samples are collected once or three times per week and automatic samplers collect 21 milliliter portions every hour. The samples are sent as collected to the Colorado River Basin Water Quality Control Project Laboratory where they are composited, filtered and analyzed for the desired radionuclides.

Radium–226 with the lowest recommended maximum permissible concentration in water of all radionuclides, has been the radioactive contaminant of greatest concern in uranium discharges. Consequently, initial and primary emphasis was placed on the analysis for radium only. In October 1963, uranium determinations were added. Beginning in July 1963, samples from selected stations were combined into quarterly composites for gamma-ray spectroscopy and analyzed for gross alpha, gross beta, strontium–90, thorium alpha, and lead–210 radioactivities. Some determinations for polonium–210 were also performed.

Analytical methods

Water samples are composited and filtered through 0.45 micron-membrane filters as soon as possible after the samples for the compositing period are received. After filtration, samples are acidified with a 2 percent by volume 12 N hydrochloric acid and radiochemical determinations are then performed on the filtered water.

Radium–226 is determined by an emanation method (*2*). Lead–210 is determined by an iodine-dithiozone extraction method (*3*). Uranium is determined by a fluorometric method, using a sodium carbonate-potassium carbonate-sodium fluoride flux (*4*). Gross alpha and beta radioactivity determinations are made on dried dissolved solids from the waters, using appropriate correction factors for self-absorption.

Strontium-90 is isolated by coprecipitation with calcium and magnesium carbonate. It is absorbed in an ion exchange column and the yttrium-90 which grows is eluted and measured. Gross gamma-ray determinations are done using a sodium iodide crystal as a detector and a scaler as the recording device.

Alpha-particle emitting thorium isotopes are determined by coprecipitation with ferric hydroxide and lanthanum fluoride followed by extraction with thenoyltrifluoroacetone, mounting, and alpha-particle counting.

Results

Radium-226 and uranium concentrations continue to average well below recommended maximum concentrations at most stations. A summary of radium-226 and uranium determinations on RMN samples for 1967 is given in tables 1 and 2. During 1967, radium-226

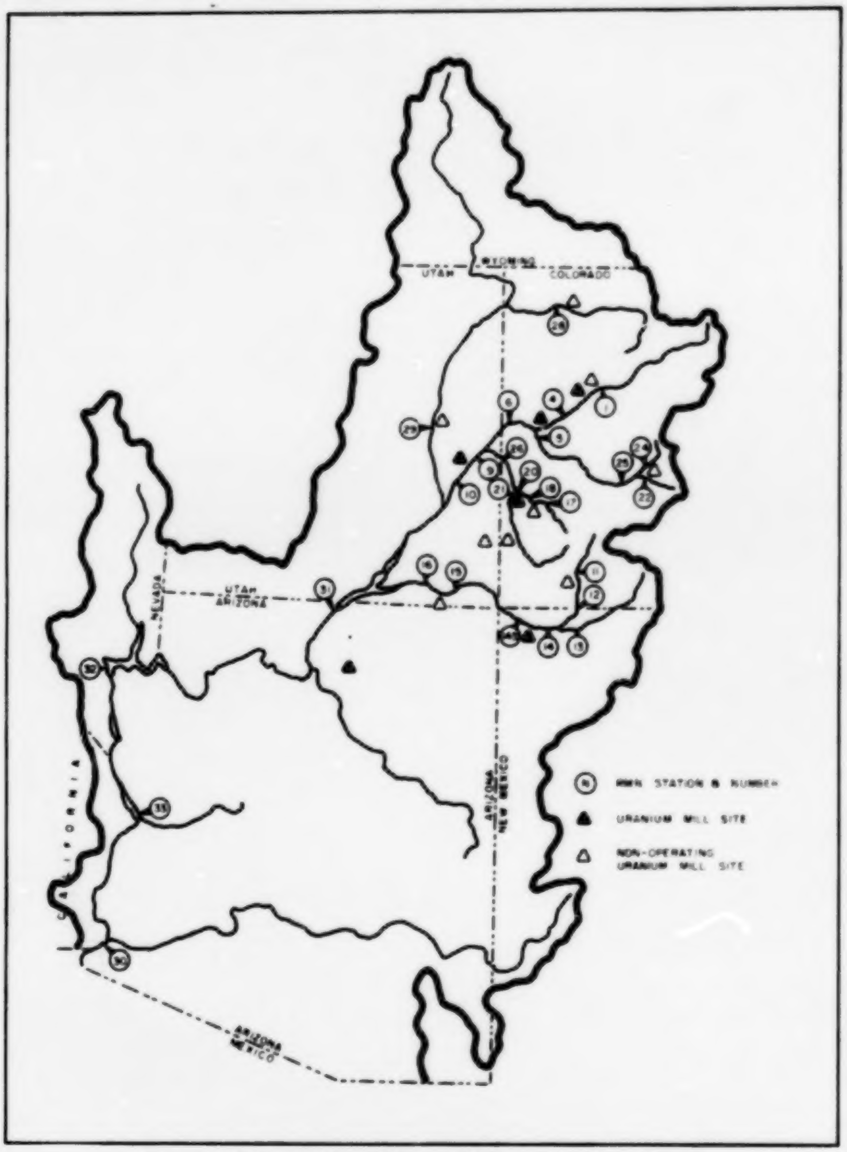
WYOMING
UTAH
COLORADO
UTAH
ARIZONA
NEVADA
CALIFORNIA
ARIZONA
NEW MEXICO
ARIZONA
MEXICO
RMN STATION & NUMBER
URANIUM MILL SITE
NON-OPERATING URANIUM MILL SITE

Figure 1. Colorado River Basin radium monitoring network

209

2

Table 1. Radium-226 in surface waters of the Colorado River basin averages January–December 1967

Sampling station number and location	Concentration (pg/liter)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Yearly average
Animas River:													
#11 above Durango, Colo	0.05	0.05	0.04	0.05	0.03	0.04	0.03	0.05	0.06	0.06	0.04	0.04	0.05
#12 Colo.-N. Mex. State line	.09	.08	.05	.09	.11	.10	.13	.09	.12	.11	.08	.08	.09
Colorado River:													
#1 at Silt, Colo	.29	.26	.20	.15	.10	.06	.13	.21	.21	.24	.26	.27	.20
#4 at De Beque, Colo	.26	.21	.23	.18	.13	.08	.14	.20	.21	.21	.22	.24	.19
#6 at Fruita, Colo	.16	.16	.16	.12	.18	.16	.22	.29	.15	.17	.16	.13	.17
#9 above Moab, Utah	.31	.25	.23	.20	.26	.17	.52	.30	.20	.17	.41	.33	.28
#10 below Moab, Utah	3.00	1.2	.99	.48	.40	.26	.33	.32	1.12	.96	.99	1.10	.93
#31 at Page, Ariz	.10	NS	.04	NS	NS	.07	.20	.19	.20	.18	.17	.15	.14
#32 Lake Mead, Nev	.41	.35	.36	.29	.30	.31	.30	.27	.29	.27	.27	.36	.31
#33 Lake Havasu, Calif	.29	.40	.38	.34	.34	.35	.37	.32	.33	.32	.31	.28	.34
#30 at Yuma, Ariz	.16	.15	.18	.19	.13	.20	.22	.20	.12	.15	.12	.20	.17
Dolores River:													
#21 at Bedrock, Colo	.54	.20	.26	.25	.16	.36	1.00	.46	.62	.83	.78	.54	.50
#26 at Gateway, Colo	1.70	2.30	1.10	1.10	.82	1.10	1.10	1.10	.82	.85	1.40	1.30	1.22
Gunnison River:													
#5 at Grand Junction, Colo	.04	.09	.06	.08	.06	.08	.12	.15	.09	.07	.08	.06	.08
San Juan River:													
#14 below Farmington, N. Mex	.05	.04	.04	.05	.06	.04	.09	.09	.07	.05	.11	.07	.06
#15 above Mexican Hat, Utah	.05	.05	.05	.08	.07	.12	.12	.08	.10	.09	.06	.08	.08
#16 below Mexican Hat, Utah	.08	.05	.06	.08	.06	.09	.12	.10	.10	.10	.07	.06	.08
San Miguel River:													
#17 above Naturita, Colo	.04	.06	.05	.04	.03	.02	.04	.06	.05	.04	.03	.04	.04
#18 above Uravan, Colo	.09	.09	.15	.09	.17	.11	.10	.25	.13	.11	.08	.06	.12
#29 below Uravan, Colo	1.80(4)	3.15(4)	1.10(5)	.94(4)	1.03(4)	2.91(5)	.42(4)	.50(4)	.64(5)	.70(4)	2.42(5)	4.15(4)	1.57

NS, no sample.
Number in parentheses indicates number of samples.

Table 2. Uranium in surface waters of the Colorado River basin averages January–December 1967

Sampling station number and location	Concentration (pg/liter)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Yearly average
Animas River:													
#11 above Durango, Colo	1.4	1.2	2.0	1.5	0.7	0.6	0.8	1.6	1.4	2.1	2.3	1.7	1.4
#12 Colo.-N. Mex. State line	2.5	1.9	3.1	2.2	1.1	1.1	3.0	1.9	2.2	3.6	3.5	2.9	2.4
Colorado River:													
#1 at Silt, Colo	3.2	3.1	4.0	2.2	1.5	1.2	1.8	2.9	3.7	3.0	4.2	3.4	2.9
#4 at De Beque, Colo	4.4	5.9	4.0	2.6	1.9	1.4	2.2	4.1	5.0	5.8	5.8	6.0	4.1
#6 at Fruita, Colo	9.5	9.0	8.0	6.2	5.2	3.9	7.1	11.0	11.0	14.0	9.1	7.3	8.4
#9 above Moab, Utah	11.0	11.0	9.0	6.4	6.9	3.8	8.5	12.0	13.0	14.0	11.0	8.7	9.6
#10 below Moab, Utah	16.0	14.0	12.0	8.5	8.4	4.3	7.2	14.0	18.0	18.0	14.0	11.0	12.1
#31 at Page, Ariz	5.2	NS	6.4	NS	NS	5.1	6.6	6.9	4.4	5.5	5.6	5.6	5.7
#32 Lake Mead, Nev	6.7	7.1	7.0	7.2	6.4	6.5	6.6	6.9	7.1	7.3	6.8	7.1	6.9
#33 Lake Havasu, Calif	7.5	7.2	8.0	8.3	7.3	7.4	6.2	7.1	6.9	6.8	7.4	7.1	7.3
#30 at Yuma, Ariz	2.0	5.9	7.4	7.4	6.8	6.5	6.5	7.6	5.1	5.8	6.0	5.6	6.1
Dolores River:													
#21 at Bedrock Colo	7.0	6.0	6.4	6.0	2.7	4.1	12.0	[illegible]	10.0	14.0	15.0	14.0	9.0
#26 at Gateway, Colo	28.0	29.0	17.0	14.0	10.0	9.5	11.0	[illegible]	19.0	36.0	30.0	32.0	20.8
Gunnison River:													
#5 at Grand Junction, Colo	15.0	11.0	9.1	5.4	4.8	7.0	14.0	13.0	13.0	15.0	7.9	5.6	10.1
San Juan River:													
#14 below Farmington, N. Mex	2.1	3.1	2.3	3.2	2.5	2.6	5.1	4.1	3.7	4.3	4.1	3.4	3.4
#15 above Mexican Hat, Utah	6.3	6.6	4.3	7.0	6.4	3.4	6.8	6.1	5.2	8.5	6.6	6.2	6.1
#16 below Mexican Hat, Utah	5.2	4.4	4.1	7.0	6.6	4.3	7.0	5.9	5.8	9.0	8.3	5.8	6.1
San Miguel River:													
#17 above Naturita, Colo	2.7	5.0	2.4	3.6	1.5	1.7	2.5	2.0	4.1	3.1	3.8	5.1	3.1
#18 above Uravan, Colo	4.7	5.0	3.7	3.5	[illegible]	2.7	2.7	4.5	5.1	3.7	5.0	5.2	4.1
#29 below Uravan, Colo	8.6(4)	8.4(4)	12.8(5)	5.7(4)	4.9(4)	12.5(5)	11.5(4)	27.6(4)	14.6(5)	11.8(4)	14.5(5)	43.3(4)	14.7

NS, no sample.
Number in parentheses indicates number of samples.

210

and uranium concentrations remained low because of the shutdown of the Durango, Colo., uranium mill in 1963.

Samples taken in the Colorado River at Moab, Utah, contained the most elevated radium-226 and uranium concentrations. The only radium-226 samples having an excess of 1.0 picogram per liter in the Colorado River were taken below Moab, Utah. The mean annual concentration of radium-226 was 0.93 picograms per liter from 0.39 for the previous year at Moab, Utah. The concentrations of radium-226 in the Colorado River at Page, Ariz., Lake Mead, Lake Havasu, and the U.S.-Mexican border showed either no significant change or slightly lower values.

Elevated radium and uranium concentrations in the Dolores River at Gateway, Colo., are attributed primarily to waste discharges from the mill at Urvan, Colo. Only the stations at Gateway and below Urvan, Colo., had annual radium averages above 1.0 picogram per liter. The mean annual concentration of radium-226 below Urvan, Colo., was down to 1.57 picograms per liter from 1.92 for the previous year. The mean annual concentrations of uranium at Gateway and below Urvan, Colo., decreased 2.6 micograms and 6.7 from the previous year respectively. The maximum concentration of uranium was 55 μg/liter detected in a sample from the Miguel River below Urvan, Colo.

REFERENCES

(*1*) COLORADO RIVER BASIN WATER QUALITY CONTROL PROJECT. Radioactivity in surface waters of the Colorado River basin, 1965–1966. Radiol Health Data Rep 9:268–271 (May 1968).

(*2*) RUSHING, D. E., W. J. GARCIA and D. A. CLARK. The analysis of effluents of environmental samples from uranium mills and of biological samples for radium, polonium, and uranium. Rad Health Safety Mining Milling Nucl Materials 11:187–230, International Atomic Energy Agency, Vienna, Austria (1964).

(*3*) TALVITIE, N. A. and W. J. GARCIA. Radiochemical determinations of lead-210 after solvent extraction as iodide and dithizonate. Anal Cham 37: 854 (1965).

(*4*) GRINALDI, F. S., I. MAY, M. H. FLETCHER, and J. PITCOMB. Collected papers on methods of analysis for uranium and thorium, USGS Bulletin 1006. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (1954).

211

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta-radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the following program was previously covered in *Radiological Health Data and Reports*.

Network	Period	Issue
HASL Fallout Network	July–December 1967	September 1968

1. Radiation Alert Network
August 1968

National Center for Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate National Center for Radiological Health officials by mail or telephone depending on levels found. Compilation of the daily field estimates is reported elsewhere on a monthly basis (1). A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during August 1968. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.

REFERENCE

(*1*) PUBLIC HEALTH SERVICE. Environmental Radiation Surveillance Report. National Center for Radiological Health, Standards and Intelligence Branch, Rockville, Md. 20852 (Distribution by official request).

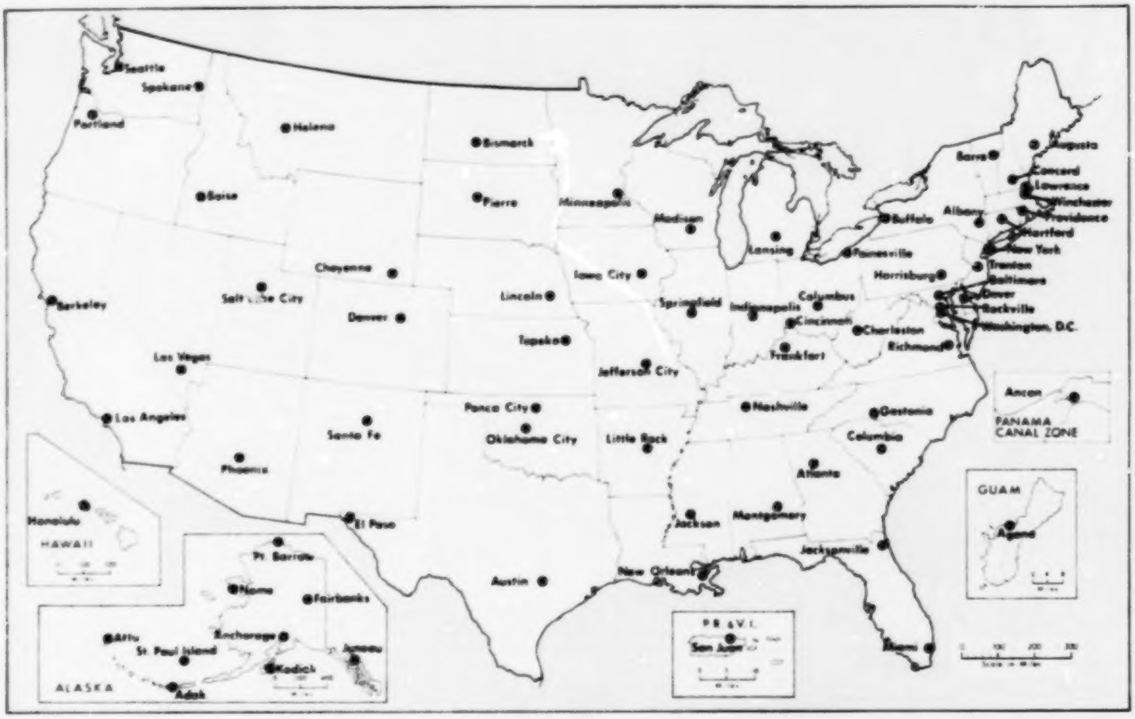
Seattle
Spokane
Portland
Helena
Bismarck
Boise
Pierre
Minneapolis
Madison
Lansing
Buffalo
Barre
Augusta
Concord
Lawrence
Winchester
Albany
Providence
Hartford
New York
Painesville
Harrisburg
Trenton
Baltimore
Dover
Rockville
Washington, D.C.
Cheyenne
Salt Lake City
Berkeley
Denver
Lincoln
Iowa City
Springfield
Indianapolis
Columbus
Cincinnati
Charleston
Richmond
Topeka
Frankfort
Jefferson City
Las Vegas
Los Angeles
Santa Fe
Ponca City
Oklahoma City
Little Rock
Nashville
Gastonia
Columbia
Atlanta
Phoenix
Ancon
PANAMA CANAL ZONE
GUAM
Agana
Honolulu
HAWAII
El Paso
Jackson
Montgomery
Jacksonville
Pt. Barrow
Nome
Fairbanks
Austin
New Orleans
Attu
Anchorage
St. Paul Island
Juneau
Kodiak
Adak
ALASKA
PR & V.I.
San Juan
Miami
0 100 200 300

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, August 1968

Station location		Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Last profile in RHD&R	Precipitation				
							Number of samples	Total depth (mm)	Field estimation of depotsition		
		Air	Maximum	Minimum	Average [a]				Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	22	6	0	2	Sept 68	6	79	6	79	86
Alaska:	Adak	29	4	1	2	Apr 68	(c)				
	Anchorage	14	0	0	0	Oct 68	(c)				
	Attu Island	(b)				May 68	(c)				
	Fairbanks	11	2	0	1	Nov 68	4	22	4	22	29
	Juneau	13	0	0	0	Dec 68	2	34	2	34	0
	Kodiak	20	2	0	1	Mar 68	(c)				
	Nome	(b)				July 68	(c)				
	Point Barrow	18	3	0	1	June 68	(c)				
	St. Paul Island	14	1	1	1	Aug 68	(c)				
Ariz:	Phoenix	20	11	0	4	Dec 68	1	3	0	0	(e)
Ark:	Little Rock	10	6	1	2	Oct 68	1	14	1	14	0
Calif:	Berkeley	21	1	0	0	Mar 68	1	3	1	3	0
	Los Angeles	(b)				July 68	(c)				
C.Z:	Ancon	17	0	0	0	Mar 68	(c)				
Colo:	Denver	19	5	1	3	Mar 68	4	33	(d)		
Conn:	Hartford	22	1	0	0	Nov 68	6	44	6	44	10
Del:	Dover	22	1	0	1	Sept 68	(c)				
D.C:	Washington	17	2	0	1	June 68	4	76	3	59	1
Fla:	Jacksonville	20	1	0	1	Oct 68	7	119	7	119	184
	Miami	20	1	0	0	Nov 68	6	153	6	153	0
Ga:	Atlanta	21	2	1	1	Aug 68	3	60	3	60	30
Guam:	Agana	17	1	0	1	Sept 68	(c)				
Hawaii:	Honolulu	31	1	0	1	May 68	(c)				
Idaho:	Boise	20	5	0	3	May 68	5	89	4	68	0
Ill:	Springfield	7	8	4	5	June 68	1	63	0	0	(e)
Ind:	Indianapolis	21	5	0	1	Aug 68	7	197	7	197	196
Iowa:	Iowa City	20	3	0	1	Mar 68	3	16	3	16	0
Kans:	Topeka	21	3	0	1	Oct 68	9	194	9	194	0
Ky:	Frankfort	6	7	1	2	June 68	(c)				
La:	New Orleans	12	1	0	0	June 68	4	42	(d)		
Maine:	Augusta	22	1	0	1	Dec 68	4	43	4	43	0
Md:	Baltimore	22	2	0	1	Nov 68	6	48	6	48	3
	Rockville	17	3	0	1	May 68	1	95	(d)		
Mass:	Lawrence	17	1	0	0	Sept 68	5	25	4	9	1
	Winchester	22	2	0	1	Apr 68	4	46	4	46	0
Mich:	Lansing	22	4	0	2	May 68	7	62	7	62	182
Minn:	Minneapolis	17	1	0	0	Sept 68	4	35	4	35	0
Miss:	Jackson	21	3	0	1	Dec 68	6	158	5	144	176
Mo:	Jefferson City	21	4	0	1	Aug 68	3	33	3	33	0
Mont:	Helena	23	5	0	3	Apr 68	5	6	5	6	6
Nebra:	Lincoln	15	4	0	2	Aug 68	5	42	5	42	0
Nev:	Las Vegas	20	5	1	3	Nov 68	(c)				
N.H:	Concord	19	3	0	1	June 68	(c)				
N.J:	Trenton	22	4	1	2	Dec 68	5	81	5	81	37
N. Mex:	Santa Fe	22	1	0	1	Apr 68	6	45	5	40	0
N.Y:	Albany	22	2	0	1	Aug 68	6	54	6	54	37
	Buffalo	21	1	0	1	Mar 68	(c)				
	New York City	21	1	1	1	Apr 68	(c)				
N.C:	Gastonia	18	8	2	5	Mar 68	(c)				
N. Dak:	Bismarck	24	8	0	2	June 68	9	144	9	144	0
Ohio:	Cincinnati	(b)				Sept 68	(c)				
	Columbus	19	5	0	2	Dec 68	4	85	3	51	0
	Painesville	20	2	0	1	Nov 68	7	26	7	26	5
Okla:	Oklahoma City	13	3	0	1	May 68	3	51	3	51	0
	Ponca City	14	3	0	2	Nov 68	4	94	3	69	35
Ore:	Portland	21	1	0	0	Aug 68	8	61	8	61	0
Pa:	Harrisburg	(b)				Aug 68	(c)				
P.R:	San Juan	(b)				Dec 68	(c)				
R.I:	Providence	21	4	0	1	May 68	6	70	5	57	35
S.C:	Columbia	21	2	0	1	Apr 68	3	43	3	43	6
S. Dak:	Pierre	14	7	2	5	Dec 68	(c)				
Tenn:	Nashville	17	2	0	1	May 68	3	42	3	42	0
Tex:	Austin	12	11	0	3	Sept 68	(c)				
	El Paso	8	4	0	1	June 68	(c)				
Utah:	Salt Lake City	31	3	0	1	July 68	9	77	9	77	26
Vt:	Barre	10	3	1	1	Oct 68	2	26	2	26	0
Va:	Richmond	18	1	0	1	Oct 68	4	93	4	93	47
Wash:	Seattle	25	3	0	0	Oct 68	9	99	(d)		
S	Spokane	22	2	0	1	Sept 68	6	30	6	30	17
W. Va:	Charleston	21	2	0	1	Apr 68	10	124	10	124	32
Wisc:	Madison	23	2	0	1	Oct 68	6	129	6	129	71
Wyo:	Cheyenne	22	7	1	4	Nov 68	5	17	5	17	31
Network summary		1,265	11	0	1		5	66	5	64	32

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] Indicates no report received (Air samples received without field estimate data are not considered by the data program.
[c] No precipitation sample collected.
[d] This station is part of the plutonium in precipitation network. No gross beta measurements are done.
[e] Samples were collected but no field estimates were received.

214

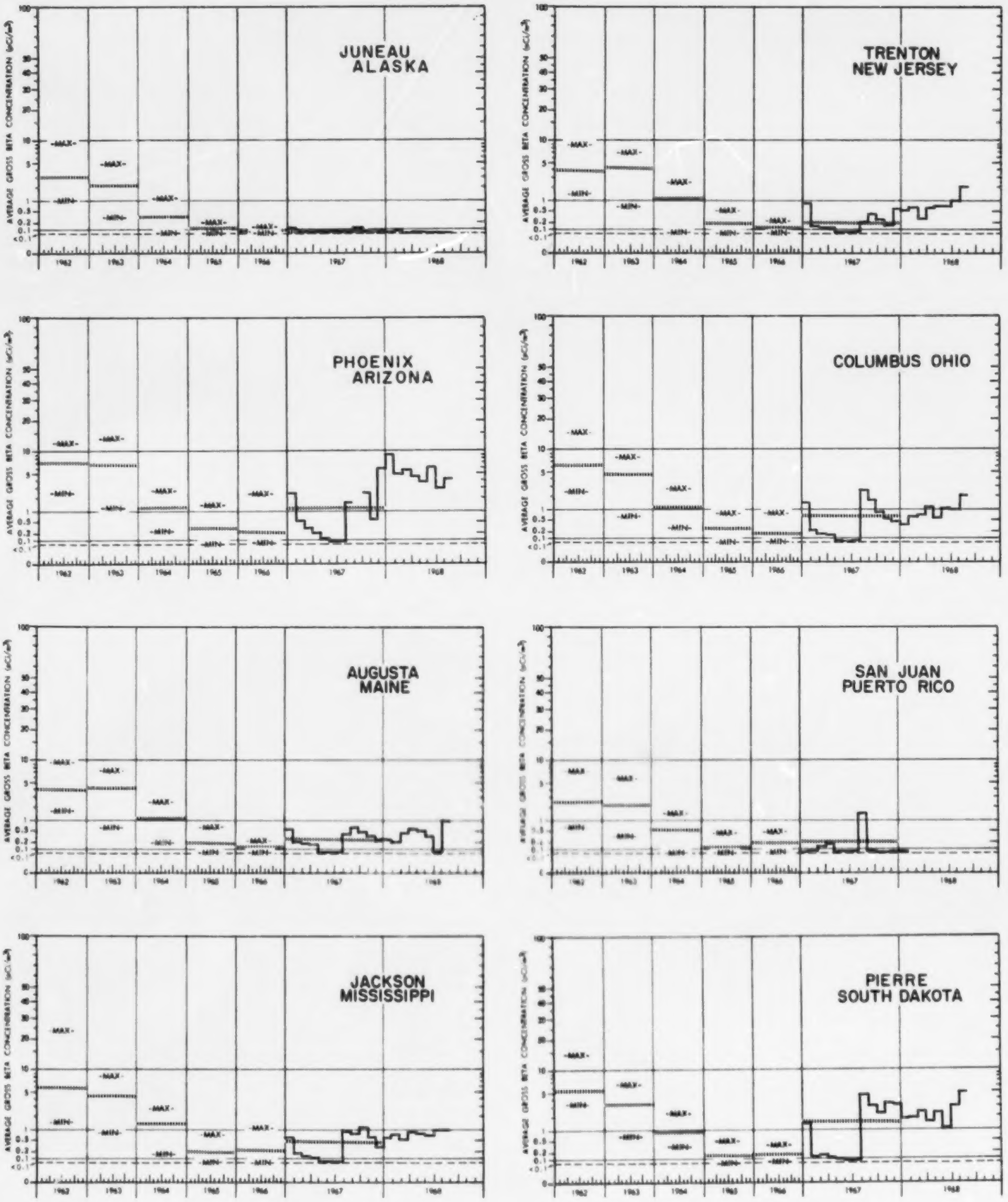

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1962–January 1968

215

2. Canadian Air and Precipitation Monitoring Program, August 1968

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meterological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the April 1968 issue of *Radiological Health Data and Reports*.

Surface air and precipitation data for August 1968 are presented in table 2.

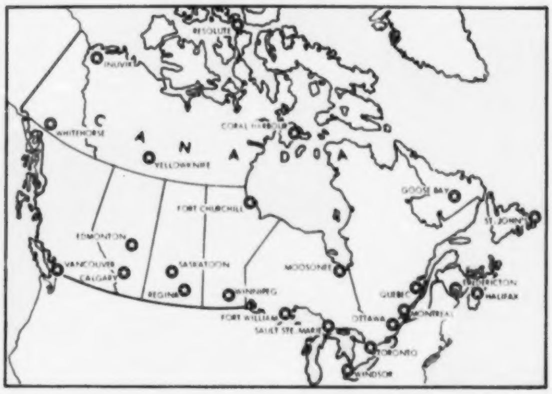

Figure 3. Canadian air and precipitation sampling stations

Table 2. Canadian gross beta radioactivity in surface air and precipitation, August 1968

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentrations (pCi/liter)	Total deposition (nCi/m²)
Calgary	31	0.3	0.0	0.1	131	3.4
Coral Harbour	21	.1	.0	.0	47	2.4
Edmonton	31	.2	.0	.1	55	3.7
Ft. Churchill	30	.2	.0	.1	58	3.4
Ft. William	31	.2	.0	.1	32	3.4
Fredericton	31	.2	.0	.1	47	2.7
Goose Bay	31	.2	.0	.1	NS	NS
Halifax	30	.2	.0	.1	51	2.7
Inuvik	31	.2	.0	.1	108	2.9
Montreal	31	.3	.0	.1	55	7.1
Moosonee	31	.2	.0	.1	11	1.7
Ottawa	31	.2	.0	.1	35	3.7
Quebec	31	.2	.0	.1	62	2.9
Regina	31	.2	.0	.1	39	4.4
Resolute	26	.1	.0	.1	25	1.1
St. John's, Nfld	31	.2	.0	.1	21	3.6
Saskatoon	30	.2	.0	.1	50	4.1
Saulte Ste Marie	31	.3	.0	.1	40	3.8
Toronto	31	.3	.0	.1	16	2.7
Vancouver	31	.2	.0	.1	50	2.5
Whitehorse	31	.2	.0	.1	39	1.9
Windsor	31	.2	.0	.1	22	1.6
Winnipeg	31	.3	.0	.1	19	2.8
Yellowknife	31	.2	.0	.1	60	1.0
Network summary	726	0.3	0.0	0.1	47	3.0

NS, no sample.

REFERENCES

(*1*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*3*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*4*) BEALE, J., and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*5*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

---

[1] Prepared from information and data in the September 1968 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

3. Pan American Air Sampling Program August 1968

Pan American Health Organization and
U.S. Public Health Service

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling locations are shown in figure 5. Analytical techniques were described in the January 1968 *Radiological Health Data and Reports*. The August 1968 air monitoring results from the participating countries are given in table 4. A noticeable increase in the monthly average concentration of gross beta radioactivity occurred in all of the countries, and fresh fission products were identified by gamma spectroscopy in several samples.

Table 4. Summary of gross beta radioactivity in Pan American surface air, August 1968

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average*
Argentina: Buenos Aires	3	0.72	0.46	0.55
Bolivia: La Paz	14	12.51	1.06	5.03
Chile: Santiago	28	10.12	.16	1.70
Colombia: Bogata	17	1.32	.02	.66
Ecuador: Guayaquil	22	4.57	.78	1.94
Guyana: Georgetown	9	.98	.08	.46
Jamaica: Kingston	14	.22	.06	.12
Peru: Lima	3	3.30	2.10	2.57
Venezuela: Caracas	21	1.79	.12	.56
West Indies: Trinidad	18	1.11	.07	.29
Pan American summary	149	12.51	0.02	1.37

* The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

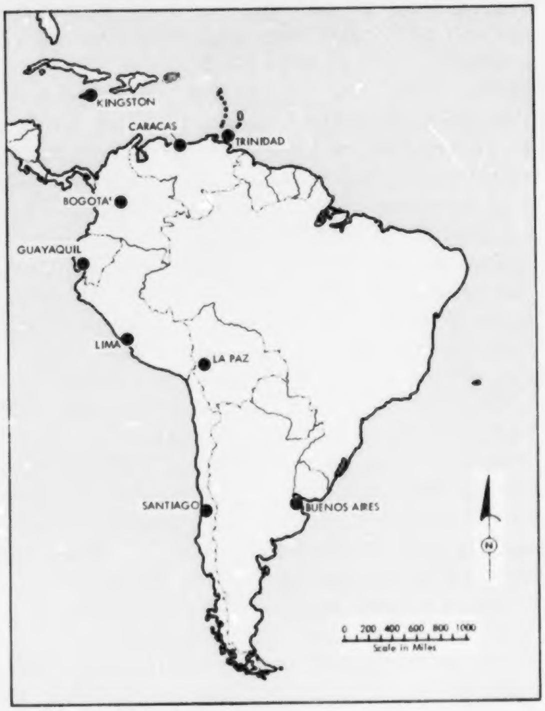

Figure 5.-- PAN AMERICAN AIR SAMPLING PROGRAM STATIONS

Figure 5. Pan American Air Sampling Program stations

---

5. Plutonium in Airborne Particulates and Precipitation, July-December 1967

National Center for Radiological Health
U.S. Public Health Service

The Radiation Alert Network (RAN) of the National Center for Radiological Health, Public Health Service, routinely analyzes airborne particulate and precipitation samples from selected RAN stations for plutonium. The airborne particulate and precipitation analyses were initiated in November 1965 and August 1966, respectively, and the results through June 1967 have been previously reported (*1–7*).

Air filters from 11 RAN stations are analyzed for plutonium. A monthly composite is made of one-half of each individual air filter from each of the 11 stations and sent to the PHS Northeastern Radiological Health Laboratory (NERHL) for analysis. Eight RAN stations submit complete collections of precipitation for plutonium analysis. An 8 liter (or whatever is available) aliquot of the monthly collection for each of the 8 stations is forwarded to the NERHL for analysis.

Beginning with the August 1967 samples, the air filters and precipitation samples have been analyzed at the NERHL for plutonium-238 and plutonium-239. The air filters are dry-ashed at 500°C. The ash is treated with nitric hydrofluoric and perchloric acids to volatilize silica, destroy any remaining organic matter and solubilize the sample. Precipitation samples are filtered through an 0.45 micron membrane paper to remove suspended solids and the solution is evaporated to a small volume. Suspended solids are subject to the same acid treatment as described for the air filter samples and then combined with the evaporated precipitation. Plutonium-236 tracer is added to the samples, the plutonium reduced to the +3 oxidation state with hydroxylamine hydrochloride and coprecipitated with lanthanum fluoride. The lanthanum fluoride is converted to lanthanum hydroxide, dissolved in 7.2 M nitric acid and the plutonium oxidized to the +4 oxidation state with sodium nitrite. The solutions are then passed over an anion exchange resin in the nitrate form. The resin is washed with additional 7.2 M nitric acid and then with 9 M hydrochloric acid. The plutonium is eluted from the resin with a mixture of 0.36 M hydrochloric acid and 0.01 M hydrofluoric acid, electroplated onto a stainless-steel planchet from a sulfuric acid-ammonium sulfate electrolyte, and counted in an alpha-particle spectrometer.

The energies of the alpha particles from plutonium–239 and plutonium–240 are not sufficiently different to be separated by alpha-particle spectrometry. Consequently, the reported plutonium–239 activities represent the sum of the activities of plutonium–239 and plutonium–240.

The samples are usually counted for at least 1,000 minutes. Reagent blanks containing plutonium–236 tracer are run concurrently with the samples. A silicon surface barrier detector with an active area of 4.5 cm² is used. With the sample electroplated onto a 3.1 cm² area, the counting efficiency is 31 percent and the resolution 75 keV (full width half maximum).

The alpha particle activity of plutonium–238 and plutonium–239 is converted to picocuries of the radionuclide per sample from the following equation:

$$ {}^{238}\mathrm{Pu}\ (\text{or } {}^{239}\mathrm{Pu}) = \frac{(A-B)\,C}{(D-E)} $$

$$ {}^{238}\mathrm{Pu}\ (\text{or } {}^{239}\mathrm{Pu}) = \text{pCi per sample of plutonium-238 (or plutoniun-239)} $$

where,

A = gross counts per minute (CPM) in plutonium–238 (or plutonium–239) spectral region,

B = reagent blank CPM in plutonium–238 (or plutonium–239) spectral region,

C = pCi plutonium–236 added,

D = gross CPM in plutonium–236 spectral region,

and,

E = background CPM in plutonium–236 spectral region.

Using these procedures, the minimum detectable activities for plutonium–238 and plutonium–239 are .020 pCi per sample and .015 pCi sample, respectively.

Prior to August 1967, the air filters and precipitation samples were analyzed for total plutonium at RAN headquarters in Rockville, Md. The analytical methodology for processing these samples has been described in earlier reports (*1, 6*).

The results for July through December 1967 are presented in tables 5 and 6. ND (not detectable) has been used to indicate samples containing plutonium–238 or plutonium–239 activities less than or equal to the appropriate minimum detectable activities. Sample size varies, generally ranging from 20,000 to 30,000 cubic meters of air for the air filter samples, and from 2 to 8 liters for the precipitation samples.

REFERENCES

(*1*) RUSSELL, J., H. LEVINE, R. SCHNEIDER. Plutonium in airborne particulates, November 1965 through March 1966. Radiol Health Data Rep 7:483–484 (August 1966).

(*2*) DIVISION OF RADIOLOGICAL HEALTH. Plutonium in airborne particulates, April–June 1966. Radiol Health Data Rep 7:666–667 (November 1966).

(*3*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Plutonium in airborne particulate, July–September 1966. Radiol Health Data Rep 8:108–109 (February 1967).

Table 5. Plutonium in airborne particulates, July–November 1967

	Buffalo	Gastonia	Rockville	Pierre	New Orleans	Austin	Denver	Anchorage	Phoenix	Honolulu	Seattle
Total plutonium: (fCi/m³)											
July	0.061	.052	.049	.077	.038	.034	.049	.031	.031	.020	.032
Plutonium 238: (fCi/m³)											
August	.0130	ND	ND	.0200	.0108	.0334	.0394	ND	.1094	NA	.0061
September	ND	.0125	.0152	.0117	.0101	.0132	.0156	.0027	NA	.0060	.0105
October	.0064	.0033	.0049	.0058	.0158	.0100	.0126	.0071	.0075	.0075	.0050
November	ND	.0037	.0029	.0056	.0056	.0024	.0076	.0108	.0108	.0066	ND
Plutonium-239: (fCi/m³)											
August	.0183	.0139	.0264	.0321	.0127	.0156	.0271	.0012	.0243	NA	.0092
September	.0177	.0202	.0189	.0219	.0221	.0140	.0172	.0042	NA	.0102	.0180
October	.0144	.0089	.0104	.0138	.0239	.0105	.0174	.0021	.0171	.0075	.0103
November	.0046	.0068	.0026	.0032	.0087	.0049	.0664	.0414	.0092	.0053	ND
$^{239}Pu/^{238}Pu$:											
August	1.41	....	....	1.61	1.18	0.47	0.69	....	0.22	....	1.51
September	....	1.61	1.24	1.87	2.18	1.06	1.10	1.56	....	1.70	1.71
October	1.78	2.70	2.12	2.38	1.82	1.95	1.38	0.30	2.28	1.00	2.06
November	....	1.84	.90	1.33	1.55	2.04	8.74	3.83	1.39	2.12	....

NA, no analysis.
ND, nondetectable.

Table 6. Plutonium in precipitation, July–December 1967 [a]

	Gastonia	Rockville	Pierre	New Orleans	Austin	Denver	Honolulu	Seattle
Precipitation depth: (mm)								
July	142	NS	1	207	9	102	35	NS
August	145	NS	NS	117	66	13	85	NS
September	45	NS	28	52	169	8	4	36
October	35	44	NS	22	85	29	37	86
November	33	62	NS	22	61	5	70	36
December	69	89	NS	65	61	5	85	42
Concentration (pCi/liter)								
Total plutonium:								
July	0.0086	....	NA	0.0071	0.1970	0.0152	0.0147	....
Plutonium-238:								
August	NA	....	....	....	NA	NA	NA	....
September	ND	....	NA	ND	ND	ND	NA	0.0030
October	ND	NA	....	.0023	ND	ND	NA	ND
November	NA	ND	....	ND	NA	.0124	NA	ND
December	ND	ND	....	ND	ND	ND	NA	.0033
Plutonium-239								
August	ND	....	....	ND	ND	NA	ND	....
September	ND	....	NA	ND	ND	.0073	NA	.0022
October	ND	.0030	....	.0072	ND	.0034	.0031	.0018
November	ND	.0025	....	ND	ND	.0075	ND	.0018
December	ND	ND	....	ND	ND	ND	NA	.0045
Deposition (pCi/m²)								
Total plutonium:								
July	1.22	....	NA	1.47	1.77	1.55	0.51	....
Plutonium-238:								
August	NA	....	....	NA	NA	NA	NA	....
September	ND	....	NA	ND	ND	ND	NA	.11
October	ND	NA	....	.05	ND	ND	NA	ND
November	NA	ND	....	ND	NA	.06	NA	ND
December	ND	ND	....	ND	ND	ND	NA	.14
Plutonium-239:								
August	ND	....	....	ND	ND	NA	ND	....
September	ND	....	NA	ND	ND	.06	NA	.08
October	ND	.13	....	.16	ND	.10	0.11	.15
November	ND	.16	....	ND	ND	.04	ND	.06
December	ND	ND	....	ND	ND	ND	NA	.19

[a] The basic finding is the concentration (pCi/1iter). This figure is multiplied by the depth of precipitation for the month (mm) to obtain the total deposition (pCi/m²). One liter of water is collected when one mm of precipitation falls on one square meter.
NA, no analysis.
ND, not detectable (see text).
NS, no sample.

(4) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Plutonium in airborne particulates, October–December 1966. Radiol Health Data Rep 8:288–289 (May 1967).

(5) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Plutonium in airborne particulates, January–March 1967. Radiol Health Data Rep 8:534 (September 1967).

(6) LEVINE, H., W. P. KIRK, H. J. L. RECHEN. Plutonium and strontium–90 in precipitation, August 1966 through March 1967. Radiol Health Data Rep 8:574–576 (October 1967).

(7) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Plutonium in airborne particulates and precipitation and strontium–90 in precipitation, April–June 1967. Radiol Health Data Rep 8:662–663 (November 1967).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Radionuclides in Alaskan Caribou and Reindeer March–May 1968

National Center for Radiological Health
U.S. Public Health Service

Under a cooperative agreement between the Alaskan Department of Health and Welfare, the Alaskan Department of Fish and Game, and the U.S. Public Health Service, an active program of caribou and reindeer sampling and analysis was undertaken in 1963 to aid in the assessment of radionuclide intake of Alaskan residents. This joint sampling activity was continued based on the results of a limited sampling effort conducted by these groups in 1962.

Through the second quarter of 1964, the sampling was confined to the three principal caribou herds and one privately-owned reindeer herd. This program was expanded in September 1964, when the sampling of additional privately-owned and government-owned reindeer herds was begun through the assistance of the Fish and Wildlife Service and the Bureau of Indian Affairs, Department of Interior.

Figure 1 shows the locations of the caribou

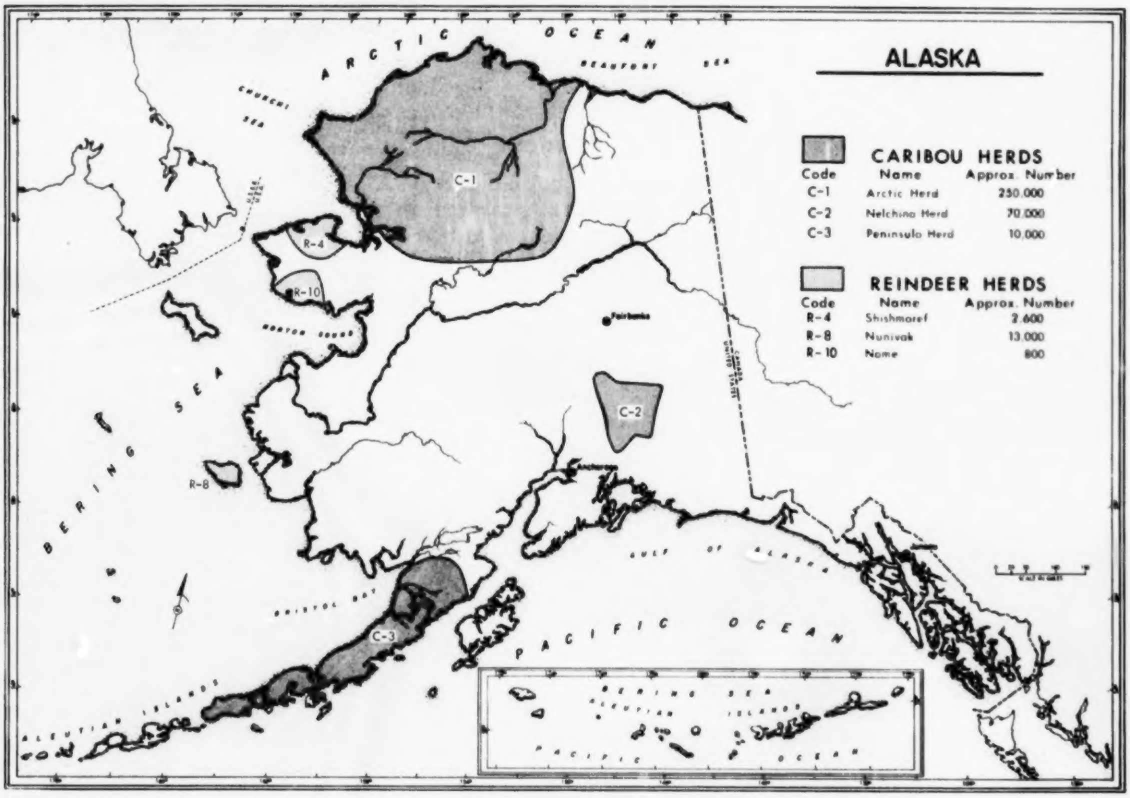
ALASKA
ARCTIC OCEAN
BEAUFORT SEA
CHUKCHI SEA
BERING SEA
NORTON SOUND
BRISTOL BAY
GULF OF ALASKA
PACIFIC OCEAN
ALEUTIAN ISLANDS
Fairbanks
C-1
C-2
C-3
R-4
R-8
R-10
CARIBOU HERDS
Code Name Approx. Number
C-1 Arctic Herd 250,000
C-2 Nelchina Herd 70,000
C-3 Peninsula Herd 10,000
REINDEER HERDS
Code Name Approx. Number
R-4 Shishmaref 2,600
R-8 Nunivak 13,000
R-10 Nome 800

Figure 1. Locations of caribou and reindeer herds sampled in Alaska

220

Table 1. Radionuclide concentrations in muscle and rumen of Alaskan caribou and reindeer, March–May 1968

Herd and sampling locations [a]	Collection date, 1968	Sex	Age (years)	Muscle (pCi/kg wet weight)			Rumen (pCi/kg wet weight)
				^{89}Sr [b]	^{90}Sr [b]	^{137}Cs	^{137}Cs
Arctic caribou herd Anaktuvuk Pass, C-1	4/25	F	9	[c] 0	25	21.0×10^{3}	5.9×10^{3}
	4/25	F	10			9.5×10^{3}	
	4/25	F	(d)			18.0×10^{3}	
	4/25	F	9			5.4×10^{3}	
	4/25	M	2			19.0×10^{3}	
Nelchina caribou herd Dickey Lake, C-2	5/9	M	5	0	35	11.0×10^{3}	5.1×10^{3}
	5/9	M	9			12.0×10^{3}	
	5/9	F	5			8.3×10^{3}	
	5/9	M	4			8.3×10^{3}	
Peninsula caribou herd King Salmon, C-3	3/16	F	3	0	20	22.0×10^{3}	1.1×10^{3}
	3/16	F	4			17.0×10^{3}	
	3/16	F	9			9.1×10^{3}	
	3/16	F	(d)			25.0×10^{3}	
	3/16	F	5			17.0×10^{3}	
Shishmaref reindeer herd, Seward Peninsula, R-4.	4/20	M	5	0	4	17.0×10^{3}	3.1×10^{3}
	4/20	M	4			17.0×10^{3}	
	4/20	M	4			13.0×10^{3}	
	4/20	M	3			17.0×10^{3}	
	4/20	M	3			13.0×10^{3}	
Nunivak Island reindeer herd, R-8	4/5	F	2	0	10	17.0×10^{3}	7.1×10^{3}
	4/5	M	5			13.0×10^{3}	
	4/5	F	5			22.0×10^{3}	
	4/5	M	4			20.0×10^{3}	
	4/5	F	5			19.0×10^{3}	
Nome reindeer herd, R-10	5/4	M	2	200	840	10.0×10^{3}	11.0×10^{3}
	5/1	M	5			19.0×10^{3}	
	5/5	M	5			14.0×10^{3}	
	5/5	M	2			20.0×10^{3}	
	5/4	F	4			17.0×10^{3}	

[a] Sampling locations are shown in figure 1.
[b] Composite of individual samples taken within herd.
[c] All results ≤ 5 pCi/kg wet weight are reported as 0.
[d] Ages not available.

and reindeer herds in Alaska that were sampled in the spring of 1968.

For the present program, samples are taken in the spring and fall from selected caribou and reindeer herds. Samples of muscle and rumen contents of five animals from each herd are collected during the sampling period. Hock joint bones from five animals are collected only from the Nome herd during the fall collection period. Muscle samples are analyzed individually and rumen content samples from each herd are composited before analysis for cesium–137 by gamma-ray spectroscopy. Muscle and bone samples from the individual herd are composited before analysis of strontium–89 and strontium–90. All samples are analyzed at the Public Health Service's Southwestern Radiological Health Laboratory in Las Vegas, Nev.

Strontium–89, strontium–90, and cesium–137 data are presented in table 1 for caribou muscle, reindeer muscle and rumen contents for the March–May 1968 collection period. The muscle data are of prime interest, since muscle is an important constituent of the diet for many Alaskan residents. A comparison of the muscle data is shown in table 2.

Table 2. Cesium–137 concentrations in caribou and reindeer muscle, spring 1967 and 1968

Herd	Average cesium-137 concentration (pCi/kg wet weight)	
	Spring 1967	Spring 1968
Arctic caribou	26×10^{3} (May)	15×10^{3} (April)
Nelchina caribou	14×10^{3} (March)	10×10^{3} (May)
Peninsula caribou	16×10^{3} (April	18×10^{3} (March)
Shishmaref reindeer	17×10^{3} (May)	15×10^{3} (April)
Nunivak reindeer	32×10^{3} (April)	18×10^{3} (April)
Nome reindeer	22×10^{3} (April)	16×10^{3} (May)

As can be seen in table 1, the cesium–137 range in muscle of individual samples within individual herds is quite large. For this reason it is very difficult to establish a definite trend. Table 2 does indicate that the cesium–137 levels in muscle during the spring of 1968 did not increase as compared to similar data in the spring of 1967. A summary of the strontium-90 and cesium-137 concentrations in foodstuffs in Alaska (including reindeer and caribou meat) is contained in the December 1966 issue of *Radiological Health Data and Reports.*

Recent coverages in *Radiological Health Data and Reports:*

Period	Issue
October-November 1966	May 1966
March-May 1967	January 1968
August-October 1967	June 1968

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major AEC installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the AEC Manual.[1]

Summaries of data from the environmental radioactivity monitoring reports follow for the Atomics International and the Paducah Plant.

---

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation," contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Atomics International[2]

January-June 1968

North American Rockwell Corporation
Canoga Park, California

Atomics International, a division of North American Aviation, Incorporated, has been engaged in atomic energy research and development since 1946. The company designs, develops, and constructs nuclear reactors for central station and compact power plants and for medical, industrial, and scientific applications.

The company headquarters is located in Canoga Park, California, approximately 23 miles northwest of downtown Los Angeles. The 290-acre Nuclear Development Field Laboratory (Santa Susana Facility), equipped with extensive testing facilities for the support of advanced nuclear studies, is in Ventura County in the Simi Hills approximately 29 miles northwest of downtown Los Angeles. The location of the above sites in relation to nearby communities is shown in figure 1.

The basic concept of radiological hazard control at Atomics International encourages total containment of radioactive materials and, through rigid operational controls, minimizes effluent releases and external radiation levels. The environmental monitoring program provides a check on the effectiveness of radiological safety procedures and of engineering safeguards incorporated into facility design.

The environs of Atomics International headquarters and Nuclear Development Field Laboratory (NDFL) are surveyed monthly to determine the concentration of radioactivity in typical surface soil, vegetation, and water samples. In addition, continuous environmental air monitoring at the sites provides information concerning airborne particulate radioactivity.

Air monitoring

Environmental air sampling is conducted continuously at the headquarters and NDFL sites with automatic air samplers operating on 24-hour sampling cycles. Airborne particulate radioactivity is collected on HV-70 filter paper which is automatically changed at the end of each sampling period. The filter is removed from the sampler and counted after the radioactivity is allowed to decay for at least 72 hours.

---

[2] Summarized from "Environmental Monitoring, semiannual report, January 1 to June 30, 1968" Atomics International, Division of North American Rockwell Corporation.

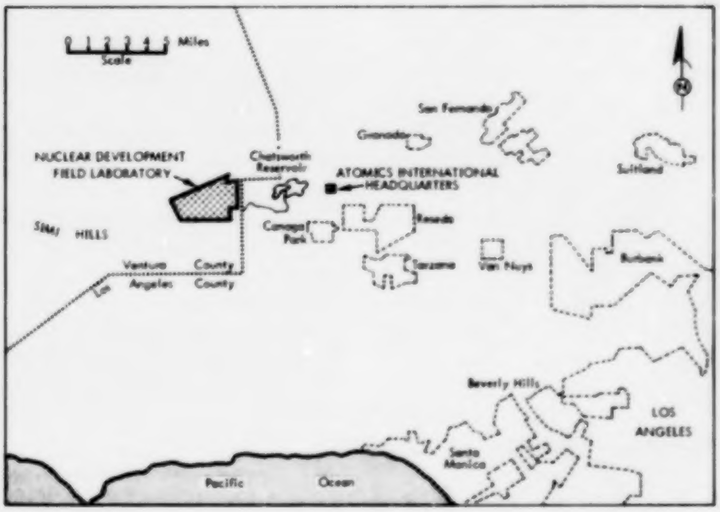
0 1 2 3 4 5 Miles
Scale
NUCLEAR DEVELOPMENT FIELD LABORATORY
Chatsworth Reservoir
ATOMICS INTERNATIONAL HEADQUARTERS
San Fernando
Granada
Sunland
SIMI HILLS
Canoga Park
Reseda
Tarzana
Van Nuys
Burbank
Ventura County
Los Angeles County
Beverly Hills
LOS ANGELES
Santa Monica
Pacific Ocean

Figure 1. Atomics International facilities and vicinity

The volume of a typical daily environmental air sample is approximately 20 cubic meters. The average concentration of long-lived beta-gamma radioactivity on airborne particulates is presented in table 1 for 1967 and the first half of 1968.

Table 1. Beta-gamma radioactivity of airborne particulates, Atomics International

Location	1967		January-June 1968	
	Number of samples	Average concentration (pCi/m³)	Number of samples	Average concentration (pCi/m³)
Headquarters	712	0.39	301	0.48
NDFL	2,400	.40	1,062	.47

Water monitoring

Process water used at the NDFL is obtained from Ventura County Water District No. 10 and distributed onsite by the same piping system previously used when process water was supplied by onsite wells. Pressure is provided by elevated storage tanks, one 50,000-gallon and one 500,000-gallon tank onsite. While clinically potable, the water is not used for drinking. Bottled potable water is delivered by a vendor and is not analyzed. Water from the pipe system is sampled monthly at two locations. The average process water radioactivity concentration is presented in table 2.

Table 2. Well water radioactivity, NDFL site Atomics International

Type of radioactivity	1967		January-June 1968	
	Number of samples	Average concentration (pCi/liter)	Number of samples	Average concentration (pCi/liter)
Alpha	24	0.12	12	0.18
Beta-gamma	24	6.1	12	4.9

Water samples are also collected monthly at Chatsworth Reservoir which is operated by the Los Angeles City Department of Water and Power. Normally, one water sample is obtained from the lake surface and a second sample is obtained from the reservoir water supply inlet located on the north side of the lake. The average radioactivity for both surface and supply water samples is presented in table 3.

Table 3. Chatsworth Reservoir water radioactivity Atomics International

Sample	Type of radioactivity	1967		January-June 1968	
		Number of samples	Average concentration (pCi/liter)	Number of samples	Average concentration (pCi/liter)
Lake surface	Alpha	12	0.31	6	0.42
	Beta-gamma	12	8.1	6	7.9
Supply inlet	Alpha	12	.28	6	.15
	Beta-gamma	12	6.0	6	4.5

Surface discharged waters from NDFL facilities drain into holding reservoirs on adjacent property. When full, the main reservoir is drained into Bell Creek, a tributary of the Los Angeles River in the San Fernando Valley, Los Angeles County. Pursuant to the requirements of Los Angeles Regional Water Quality Control Board Resolution 66–49 of September 21, 1966, an environmental sampling station has been established in Bell Creek Canyon approximately 3.4 miles downstream from the south NARC boundary. Samples obtained and analyzed monthly, include stream bed mud, vegetation, and water. Average radioactivity concentrations in the main holding reservoir and Bell Creek samples are presented in table 4.

Table 4. Radioactivity in the Rocketdyne Reservoir [a] and Bell Creek, Atomics International, January–June 1968

Sample description (units)	Number of samples	Alpha radioactivity	Beta radioactivity
Reservoir Station 6 [a] (pCi/liter)	6	0.26	7.1
Reservoir Station 12 [a] (pCi/liter)	6	.58	8.4
Bell Creek mud (pCi/g)	5	.31	23
Bell Creek vegetation (pCi/g ash)	5	.35	171
Bell Creek water (pCi/liter)	5	.07	4.3

[a] Locations not shown on figure 1.

Soil and vegetation monitoring

Soil and vegetation are regularly sampled at 24 locations. Twelve sampling stations are located within the boundaries of Atomics International's sites and are referred to as "onsite" stations. The remaining 12 stations, located within a 10-mile radius of the sites, are referred to as "offsite" stations.

Surface soil types available for sampling range from decomposed granite to clay and loam. Samples are taken from the top half-inch layer of ground surface. The soil samples are packaged and sealed in plastic containers and returned to the laboratory for analysis. Radioactivity in soil samples is presented in table 5.

Table 5. Radioactivity in the soil, Atomics International

Area	Type of radioactivity	1967		January–June 1968	
		Number of samples	Average concentration (pCi/g)	Number of samples	Average concentration (pCi/g)
Onsite	Alpha	144	0.41	72	0.47
	Beta-gamma	144	28	72	25
Offsite	Alpha	48	.38	24	.50
	Beta-gamma	48	24	24	25

Vegetation samples obtained in the field are of the same plant type wherever possible, generally, sunflower or wild tobacco plant leaves. These types maintain a more active growth rate during the dry season than do most natural vegetation indigenous to the local area. Vegetation leaves are stripped from plants and transferred to the laboratory for analysis. Plant root systems are not routinely sampled. Radioactivity in vegetation samples is presented in table 6.

Table 6. Radioactivity in vegetation, Atomics International

Area	Type of radioactivity	1967		January–June 1968	
		Number of samples	Average concentration (pCi/g ash)	Number of samples	Average concentration (pCi/g ash)
Onsite	Alpha	144	0.61	72	0.55
	Beta-gamma	144	286	72	177
Offsite	Alpha	48	.38	24	.55
	Beta-gamma	48	413	24	273

Recent coverage in *Radiological Health Data and Reports*:

Period	Issue
January–June 1967	March 1968
July–December 1967	June 1968

2. Paducah Plant[3]
January–June 1968

Union Carbide Corporation
Paducah, Kentucky

The Paducah Plant is a government-owned gaseous diffusion plant operated by the Nuclear Division of the Union Carbide Corporation for the Atomic Energy Commission. The diffusion plant processes large quantities of relatively pure uranium compounds. The uranium hexafluoride manufacturing plant, a former source of diffusion plant feed, was placed on standby in June of 1964. Parts of the associated uranium metal foundry, usually on standby, are operated infrequently as the need arises. A decontamination and uranium recovery facility operates to prepare equipment for repair and to recover impure or scrap uranium materials. Depleted uranium metal is fabricated into shields, weights, ballasts, or other shapes on a nonroutine basis. The major sources of external penetrating radiation are the daughter products of uranium, thorium-234, and protactinium-234, which may be concentrated by uranium recovery processes or by uranium hexafluoride vaporization. The element, uranium can be a physiological hazard only if allowed to enter the body. The chemical toxicity of the uranium processed at the Paducah Plant overshadows any probable biological effects of radiation from this element, thus making it comparable as a physiological hazard to lead, mercury, or other well-known heavy metals.

Because of the necessity for health protection in process areas, the high intrinsic value of uranium, and the desire to maintain a wholesome relationship with neighboring communities and individuals, the Paducah Plant provides confinement and recovery systems at the plant. The environmental monitoring program provides for continuously sampling the air at four stations around the plant perimeter fence, and at five stations located approximately 1 mile outside this fence (figure 2). Big Bayou Creek water is sampled continuously, and grab samples are collected at five locations in the Ohio River. In addition, gamma radiation readings are taken each month at each of the air sampling stations with a Geiger-Mueller type meter at a distance of 3 feet above ground level.

Basic standards

The radiation protection standards observed at the Paducah Plant for exposure to radiation and radioactive materials, both for the in-plant work environment of employees and for offsite exposure of the general population, are those contained in Appendix 0524 of the AEC manual.

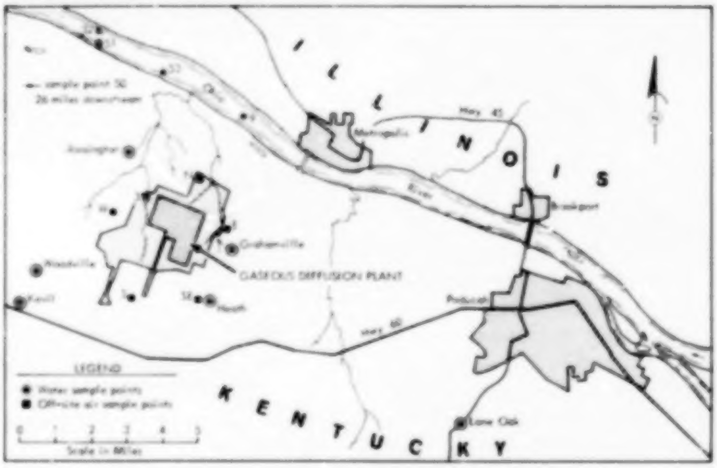

Figure 2. Sampling locations, Paducah Plant

---

[3] Summarized from "Environmental Concentrations of Radioactive Materials Near the Paducah Plant—Report for the First Half of 1968."

The standards specify that the radiation or radioactive materials outside a controlled area, and which have resulted from operations within that controlled area, shall be such that it is improbable that any individual may receive a dose of external radiation greater than 0.5 rem in any year and that the average exposure of a suitable population sample may not exceed one-third of this dose. To meet this standard, the average concentration of radionuclides in air or water beyond a controlled area should not exceed one-tenth of the maximum permitted for occupational exposure of 168 hours per week. For the purposes of such control, the concentrations of such radionuclides in air or water may be averaged over periods of time up to 1 year.

Discussion

Data summarizing the environmental concentrations of radioactive materials in air and water and the gamma radiation levels in the vicinity of the Paducah Gaseous Diffusion Plant are presented in tables 7 through 10.

Air samples were collected continuously at each of the four stations at the plant perimeter fence and at five stations about 1 mile outside the plant. Air is filtered at 0.3 cfm through 2-inch diameter membrane filters which are replaced weekly and counted for alpha and beta radioactivity.

The average alpha-particle count—interpreted as uranium, the most likely source of radioactivity—of the 234 air samples collected during the first half of 1968 was less than 1 percent of the AEC standard set for individuals residing in the vicinity of a controlled area. The average beta-particle count of the same samples was 0.02 percent of the standard.

The average uranium analyses of weekly water samples collected continuously from the Big Bayou Creek during the first half of 1968 was 0.02 percent of the AEC standard for water beyond a controlled area. The results of the uranium analyses for each of the 6 grab samples collected at monthly intervals from the Ohio River below the plant, were less than 0.01 percent of the AEC standard.

The concentration of beta-particle emitters in the Big Bayou Creek averaged less than 0.5 percent of the AEC standard for the decay products of uranium-238. The beta radioactivity of the Ohio River was less than 0.5 percent of the standard for uranium-238 decay products.

External gamma radiation in the vicinity of the Paducah Plant averaged 0.02 mR/hr at all sampling stations for January–June 1968.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1967	January 1968
July–December 1967	May 1968

Table 7. Uranium concentrations in outdoor air samples Paducah Plant, January–June 1968

Sample location [a]	Number of samples	Uranium alpha radioactivity [b] (pCi/m^3)		
		Maximum	Minimum [c]	Mean [d]
At plant perimeter fence:				
North	26	0.04	<0.02	<0.02
East	26	.04	< .02	< .02
South	26	.02	< .02	< .02
West	26	.02	< .02	< .02
Total	104	0.04	<0.02	<0.02
About 1 mile outside plant perimeter fence:				
North	26	.02	< .02	< .02
East	26	.02	< .02	< .02
South	26	.02	< .02	< .02
West	26	.03	< .02	< .02
Southeast	26	.03	< .02	< .02
Total	130	0.03	<0.02	<0.02

[a] See map in figure 1.

[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57×10^4 alpha dis/sec.

[c] The minimum detectable concentration of uranium in air is 0.02 pCi/m^3.

[d] The AEC standard for natural uranium in air released to the environs beyond a controlled area is 2 pCi/m^3.

Table 8. Beta radioactivity in outdoor air samples Paducah Plant, January–June 1968

Sample location [a]	Number of samples	Beta radioactivity (pCi/m^3)		
		Maximum	Minimum [b]	Mean [c]
At plant perimeter fence:				
North	26	0.36	<0.1	0.20
East	26	.43	< .1	.20
South	26	.43	< .1	.15
West	26	.57	< .1	.20
Total	104	0.57	<0.1	0.19
About 1 mile outside plant perimeter fence:				
North	26	.66	< .1	.22
East	26	.69	< .1	.20
South	26	.72	< .1	.24
West	26	.61	< .1	.21
Southeast	26	.49	< .1	.21
Total	130	0.72	<0.1	0.22

[a] See map in figure 1.

[b] The minimum detectable amount of beta-particle emitters in air is 0.1 pCi/m^3.

[c] The AEC standard, applicable to this table is 1×10^3 pCi/m^3, which is the concentration limit of thorium-234, the daughter product of uranium-238. Insignificant amounts of other daughters are present in freshly refined uranium.

Table 9. Concentrations of uranium in water Paducah Plant, January–June 1968

Sample location [a]	Number of samples	Uranium [b] (pCi/liter)		
		Maximum	Minimum [c]	Mean [d]
Big Bayou Creek 3	26	11	<1	3
Ohio River	6	< 1	<1	<1
Composite of 50, 51, 52, and 53	6	2	<1	<1

[a] See map in figure 1.

[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57×10^4 dis/sec.

[c] The minimum detectable uranium in water is 1 pCi/liter.

[d] The AEC standard for natural uranium in water beyond a controlled area is 2×10^4 pCi/liter.

Table 10. Concentration of beta-particle emitters in water, Paducah Plant, January–June 1968

Sample location [a]	Number of samples	Beta-particle emitters (pCi/liter)		
		Maximum	Minimum [b]	Mean [c]
Big Bayou Creek 3	26	200	<100	<100
Ohio River 9	6	400	<100	100
Composite of 50, 51, 52, and 53	6	<100	<100	<100

[a] See map in figure 1.

[b] The minimum detectable amount of beta-particle emitters in water is 100 pCi/liter.

[c] The AEC standard for the immediate daughter products of uranium in water released to the environs is 2×10^4 pCi/liter.

Reported Nuclear Detonations, November 1968

The U.S. Atomic Energy Commission announced five underground nuclear tests conducted at its Nevada Test Site during November 1968.

The tests of November 3, 15, 20 and 22 were of low yield (less than 20 kilotons TNT equivalent). The test of November 4 was in the low-intermediate (20 to 200 kilotons TNT equivalent) yield range.

On November 7, 1968, it was announced by the Commission that the United States had recorded seismic signals originating from the Soviet northern testing area in the Novaya Zemlya region. The signals were equivalent to those of a nuclear test in the lower end of the intermediate yield range (200 kilotons to one megaton TNT equivalent).

Annual Subject Index

Radiological Health Data and Reports

Volume 9–1968

A

A comparison of results between the Public Health raw milk and pasteurized milk networks for January 1964 through June 1966, *Sept:475*
Air—*see* atmospheric contaminants; fallout
Alabama
  Radium survey in Alabama, *Jan:16*
  Survey of therapeutic x-ray installations in Alabama, *Jan:13*
Alaska
  Cesium-137 concentrations in Alaskans during the spring of 1967, *Dec:*
  Radionuclides in Alaskan caribou and reindeer,
    Mar-May 1967, *Jan:53*
    Aug-Oct 1967, *June:320*
    Mar-May 1968, *Dec:764*
Alpha radioactivity in coal mine drainage, *Dec:725*
Alpha radiation exposure levels in underground uranium and other mines, *Dec:719*
A pilot survey of x-radiation emissions from color television receivers in Pinellas County, Florida, *Oct:525*
A procedure for evaluating environmental radiation dose to children in the vicinity of the Hanford project in Washington, April 1965-January 1967, *Aug:402*
Argonne National Laboratory
  Jan-June 1967, *Mar:184*
  July-Dec 1967, *Aug:459*
A summary of the Washington, D.C. metropolitan area survey of color television receivers, *Oct:531*
Atmospheric contaminants
  Tritiated moisture in the atmosphere surrounding a nuclear fuel reprocessing plant, *July:341*
  Plutonium in airborne particulates and precipitation, July-December 1967, *Dec:*
  Offsite environmental surveillance findings associated with underground nuclear testing, Project Dribble, *Feb:73*
Atmospheric levels of radioactivity—*see*
  atmospheric contaminants; nuclear testing; environmental levels of radioactivity at Atomic Energy Commission installations; fallout; reported nuclear detonations
Atomic Energy Commission installations—*see*
  Argonne; Atomics International; Feed Materials Production Center; Hanford; Lawrence; Los Alamos; Mound; National; Oak Ridge, Paducah: Pinellas; Portsmouth; Rocky Flats; Savannah
Atomics International
  Jan-June 1967, *Mar:188*
  July-Dec 1967, *June:327*
  Jan-June 1968, *Dec:766*

B

Barium-lanthanum-140—*see* atmospheric contaminants; Atomic Energy Commission installations; fallout; milk
Body burdens
  A procedures for evaluating environmental radiation dose to children in the vicinity of the Hanford project in Washington, April 1965-January 1967, *Aug:402*
  Levels of iron-55 in humans, animals and food, 1964-1967, *Aug:387*
  Summary of iron-55 contamination in the environment and levels in humans, *Apr:195*
Bone
  Strontium-90 in human bone
    Jan-Mar 1967, *June:323*
    Apr-June 1967, *Sept:514*
Bovine thyroids
  Iodine-131 in bovine thyroids
    Apr-Sept 1967, *Feb:120*
    Oct-Dec 1967, *May:280*
    Jan-Mar 1968, *Aug:456*
    Apr-June 1968, *Nov:695*

C

Calcium—*see also* diet; milk
  A comparison of results between the Public Health Service raw milk and pasteurized milk networks for January 1964 through June 1966, *Sept:475*
California
  California Milk Network
    July-Sept 1967, *Mar:160*
    Oct-Dec 1967, *June:296*
    Jan-Mar 1968, *Sept:496*
    Apr-July 1968, *Nov:637*
    August 1968, *Dec: 730*
  Detection of elevated fallout levels in California, January 1967, *Sept:467*
  Estimated daily intake of radionuclides in California diets
    Mar-June 1967, *Feb:102*
    July-Oct 1967, *May:261*
  Radioactivity in California waters
    July-Dec 1967, *Feb:108*
    Jan-June 1968, *June:308*
    July-Dec 1968, *Nov:667*
Canada
  Canadian Air and Precipitation Monitoring Program
    Sept 1967, *Jan:49*
    Oct 1967, *Feb:116*
    Nov 1967, *Mar:177*
    Dec 1967, *Apr:229*
    Jan 1968, *May:276*
    Feb 1968, *June:316*
    Mar 1968, *July:375*
    Apr 1968, *Aug:419*
    May 1968, *Sept:493*
    June 1968, *Oct:549*
    July 1968, *Nov:677*
    Aug 1968, *Dec:760*

Canadian Milk Network Program
Sept 1967, *Jan:24*
Oct 1967, *Feb:89*
Nov 1967, *Mar:157*
Dec 1967, *Apr:207*
Jan 1968, *May:247*
Feb 1968, *June:293*
Mar 1968, *July:351*
Apr 1968, *Aug:419*
May 1968, *Sept:493*
June 1968, *Oct:549*
July 1968, *Nov:635*
Aug 1968, *Dec:730*
Cesium-137—*see also* Colorado; Florida; milk
Cesium-137 concentrations in Alaskans during the spring of 1967, *Dec:705*
Cesium-137 in milk from the Colorado State University dairy herd, *Aug:412*
Cesium-137 levels in Florida beef-variations with feeding program, *Aug:391*
Whole body cesium-137 and its relation to body composition and diet, *Nov:619*
Color television receivers
A pilot survey of x-radiation emissions from color television receivers in Pinellas County, Florida, *Oct:525*
A summary of the Washington, D.C. metropolitan area survey of color television receivers, *Oct:531*
Colorado
Colorado Milk Network
July-Sept 1967, *Jan:27*
Oct-Dec 1967, *Apr:210*
Jan-Mar 1968, *July:354*
Apr-June 1968, *Oct:552*
July 1968, *Nov:639*
August 1968, *Dec:730*
Gamma-emitting fallout in surface air at Fort Collins, Colorado, 1962-1967, *Aug:407*
Radioactivity in surface waters of the Colorado River basin
1965-1966, *May:268*
1967, *Dec:752*
Comparison of environmental radioactivity levels after foreign nuclear tests of May 9, 1966, and December 27, 1966, *Feb:63*
Connecticut
Connecticut Milk Network
July-Sept 1967, *Feb:92*
Oct-Dec 1967, *May:250*
Jan-Mar 1968, *Aug:423*
Apr-July 1968, *Nov:640*
August 1968, *Dec:730*
Estimated daily intake of radionuclides in Connecticut standard diet
July-Dec 1967, *May:264*
Jan-June 1968, *Nov:657*

D

Dental x ray
Thermoluminescent radiation dosimetry applied to dental x-ray exposures, *Aug:397*
Detection of elevated fallout levels in California, January 1967, *Sept:467*
Detonations, nuclear—*see* foreign nuclear tests; reported nuclear detonations
Diet
Estimated daily intake of radionuclides in diets—*see also* California; Connecticut
Radionuclides in Institutional diet samples
Apr-June 1967, *Jan:34*
July-Sept 1967, *Apr:217*
Oct-Dec and annual summary 1967, *July:359*
Jan-Mar 1968, *Oct:557*
Strontium-90 in Tri-City diets
Jan-June 1967, *Mar:166*
Apr-Dec 1967, *June:302*
Whole body cesium-137 and its relation to body composition and diet, *Nov:619*
Drinking water analysis program, 1961-1966, *PHS, Aug:442*

E

Environmental levels of radioactivity at Atomic Energy Commission installations—*see* Argonne, Atomics International; Feed Materials Production Center; Hanford; Lawrence; Mound; National; Oak Ridge; Paducah; Pinellas; Portsmouth; Rocky Flats; Savannah.
Environmental levels of radioactivity in Mexico, January-June 1967, *Oct:578*
Environmental surveillance
Comparison of environmental radioactivity levels after foreign nuclear weapons tests of May 9, 1966 and December 27, 1966, *Feb:63*
Offsite environmental surveillance findings associated with underground nuclear testing; Project Dribble, *Feb:73*
Exposures—*see also* color television receivers, x-ray
Alpha radiation exposure levels in underground uranium and other mines, *Dec:719*
Thermoluminescent radiation dosimetry applied to dental x-ray exposures, *Aug:397*

F

Fallout
Detection of elevated fallout levels in California, January 1967, *Sept:467*
Fallout in the United States and other areas, *HASL*
Jan-June 1967, *Mar:180*
July-Dec 1967, *Sept:511*
Gamma emitting fallout in surface air at Fort Collins, Colorado, 1962-1967, *Aug:407*
Feed Materials Production Center
Jan-June 1967, *Mar:190*
July-Dec 1967, *Aug:463*
Field measurements of natural background gamma radiation using a calibrated portable scintillation counter, *Nov:679*
Florida
A pilot survey of x-radiation emissions from color television receivers in Pinellas County, Florida, *Oct:525*
Cesium-137 levels in Florida beef-variations with feeding program, *Aug:391*
Florida Milk Network
July-Sept 1967, *Jan:28*
Oct-Dec 1967, *Apr:211*
Jan-Mar 1968, *July:355*
Apr-June 1968, *Oct:553*
July 1968, *Nov:641*
August 1968, *Dec:730*
Radioactivity in Florida waters, 1965-1966 *July:368*
Fluoroscopy
Personnel monitoring of radiologists during fluoroscopy, *Nov:627*
Food—*see also* diet; milk;
A procedure for evaluating environmental radiation dose to children in the vicinity of the Hanford project in Washington, April 1965-January 1967, *Aug:402*
Levels of iron-55 in humans, animals, and food, 1964-1967, *Aug:387*
Foreign nuclear weapons tests
Comparison of environmental radioactivity levels after foreign nuclear weapons tests of May 9, 1966 and December 27, 1966, *Feb:63*

- French nuclear weapons tests,
  - July-October 1966 and June-July 1967, *Apr:241*

G

- Gamma-emitting fallout in surface air at Fort Collins, Colorado, 1962-1967, *Aug:407*
- Gross radioactivity, May 1968, and strontium-90, July-September 1967 in surface waters of the United States, *Nov:660*
- Gross radioactivity of the solids in selected surface waters of the United States, 1961-1965, *Jan:1*

H

- Hanford Atomic Products Operation
  - Calendar year 1966, *Feb:123*
  - A procedure of evaluating environmental radiation dose to children in the vicinity of the Hanford Project in Washington, April 1965-January 1967, *Aug:402*

I

- Indiana
  - Indiana Milk Network
    - July-Sept 1967, *Feb:93*
    - Oct-Dec 1967, *May:251*
    - Jan-Mar 1968, *Aug:424*
    - Apr-July 1968, *Nov:642*
    - August 1968, *Dec:730*
- Iodine-131—*see also* fallout; milk
  - Iodine-131 in bovine thyroids, *PHS*
    - Apr-Sept 1967, *Feb:120*
    - Oct-Dec 1967, *May:280*
    - Jan-Mar 1968, *Aug:456*
    - Apr-June 1968, *Nov:695*
- Iowa
  - Iowa Milk Network
    - July-Sept 1967, *Feb:94*
    - Oct-Dec 1967, *May:252*
    - Jan-Mar 1968, *Aug:425*
    - Apr-July 1968, *Nov:643*
    - August 1968, *Dec:730*
- Iron-55
  - Levels of iron-55 in humans, animals, and food, 1964-1967, *Aug:387*
  - Summary of iron-55 contamination in the environment and levels in humans, *Apr:195*

J, K, L

- Kansas
  - Radioactivity in Kansas surface waters, July-December 1967, *Nov:671*
- Lawrence Radiation Laboratory
  - Jan-June 1967, *Apr:233*
  - July-Dec 1967, *Sept:518*
- Levels of iron-55 in humans, animals, and food 1964-1967, *Aug:387*
- Los Alamos Scientific Laboratory
  - Calendar year 1967, *Nov:701*

M

- Mexico
  - Environmental levels of radioactivity in Mexico, January-June 1967, *Oct:578*
  - Mexican Air Monitoring Program
    - Sept 1967, *Jan:50*
    - Oct 1967, *Feb:117*
    - Nov 1967, *Mar:178*
    - Dec 1967, *Apr:230*
    - Jan 1968, *May:277*
    - Feb 1968, *June:317*
    - Mar 1968, *July:376*
    - Apr 1968, *Aug:414*
    - May 1968, *Sept.509*
- Michigan
  - Michigan Milk Network
    - July-Sept 1967, *Feb:96*
    - Oct-Dec 1967, *May:254*
    - Jan-Mar 1968, *Aug:426*
    - Apr-July 1968, *Nov:645*
    - August 1968, *Dec:730*
- Milk
  - A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966, *Sept:475*
  - Cesium-137 in milk from the Colorado State University dairy herd, 1962-1967, *Aug:412*
  - National and International milk surveillance—*see* Canada; Pan American Health Organization; Pasteurized Milk Network
  - Radiostrontium in milk
    - January-December 1967, *Aug:420*
  - State Milk Surveillance Activities—*see* California; Colorado; Connecticut; Florida; Indiana; Iowa; Michigan; Minnesota; New York; Oklahoma; Oregon; Pennsylvania; Tennessee; Texas; Washington
- Minnesota
  - Minnesota Milk Network
    - July-Sept 1967, *Feb:98*
    - Oct-Dec 1967, *May:255*
    - Jan-Mar 1968, *Aug:428*
    - Apr-July 1968, *Nov:647*
    - August 1968, *Dec:730*
  - Radioactivity in Minnesota municipal water supplies
    - Jan-June 1967, *Jan:40*
    - July-Dec 1967, *Oct:566*
  - Mound Laboratory
    - Jan-June 1967, *Apr:238*
    - July-Dec 1967, *Sept:522*

N

- National and International milk surveillance—*see* milk
- National Reactor Testing Station
  - Jan-June 1967, *Mar:192*
  - July-Dec 1967, *Oct:610*
- New York
  - New York Milk Network
    - July-Dec 1967, *May:257*
    - Jan-Mar 1968, *Aug:430*
    - Apr-July 1968, *Nov:649*
    - Aug 1968, *Dec:730*
  - Radioactivity in New York surface water
    - Jan-May 1967, *Jan:42*
    - June-Dec 1967, *Oct:568*
- Nuclear detonations—*see also* reported nuclear detonations
  - Offsite environmental surveillance findings associated with underground nuclear testing, Project Dribble, *Feb:73*

O

- Oak Ridge Area
  - Jan-June 1967, *July:379*
  - July-Dec 1967, *Oct:613*

- Occupational exposure
  - Alpha radioactivity in coal mine drainage in western Pennsylvania, *Dec:725*
  - Alpha radiation exposure levels in underground uranium and other mines, *Dec:719*
  - Personnel monitoring of radiologists during fluoroscopy, *Nov:627*
  - Radium survey in Alabama, *Jan:16*
  - Suggested biological monitoring for radon daughter exposure, *Feb:81*
  - Survey of therapeutic x-ray installations in Alabama, *Jan:13*
  - Thermoluminescent radiation dosimetry applied to dental x-ray exposures, *Aug:397*
  - Tritiated moisture in the atmosphere surrounding a nuclear fuel reprocessing plant, *July:341*
- Offsite environmental surveillance findings associated with underground nuclear testing; Project Dribble, *Feb:73*
- Oklahoma
  - Oklahoma Milk Network
    - July-Sept 1967, *Jan:29*
    - Oct-Dec 1967, *Apr:212*
- Oregon
  - Oregon Milk Network
    - July-Sept 1967, *Mar:162*
    - Oct-Dec 1967, *June:298*
    - Jan-Mar 1968, *Sept:497*
    - Apr-July 1968, *Nov:651*
    - August 1968, *Dec:730*

P

- Paducah Plant
  - Jan-June 1967, *Jan:56*
  - July-Dec and calendar year 1967, *May:282*
  - Jan-June 1968, *Dec:769*
- Pan American Health Organization
  - Pan American Air Sampling Program
    - Sept 1967, *Jan:51*
    - Oct 1967, *Feb:118*
    - Nov 1967, *Mar:179*
    - Dec 1967, *Apr:232*
    - Jan 1968, *May:278*
    - Feb 1968, *June:318*
    - Mar 1968, *July:377*
    - Apr 1968, *Aug:455*
    - May 1968, *Sept:510*
    - June 1968, *Oct:576*
    - July 1968, *Nov:678*
    - Aug 1968, *Dec:761*
  - Pan American Milk Sampling Program
    - Sept 1967, *Jan:25*
    - Oct 1967, *Feb:90*
    - Nov 1967, *Mar:158*
    - Dec 1967, *Apr:208*
    - Jan 1968, *May:248*
    - Feb 1968, *June:294*
    - Mar 1968, *July:352*
    - Apr 1968, *Aug:420*
    - May 1968, *Sept:494*
    - June 1968, *Oct:550*
    - July 1968, *Nov:636*
    - Aug 1968, *Dec:730*
- Particulates—*see* atmospheric contaminants; fallout; Radiation Alert Network, Radiation Surveillance Network, radioactivity in airborne particulates and precipitation
- Pasteurized Milk Network
  - Sept 1967, *Jan:20*
  - Oct 1967, *Feb:86*
  - Nov 1967, *Mar:154*
  - Dec 1967, *Apr:204*
  - Jan 1968, *May:244*
  - Feb 1968, *June:290*
  - Mar 1968, *July:352*
  - Apr 1968, *Aug:416*
  - May 1968, *Sept:490*
  - June 1968, *Oct:546*
  - July 1968, *Nov:632*
  - Aug 1968, *Dec:730*
  - A comparison of results between the Public Health Service raw milk and pasteurized milk networks for January 1964 through June 1966, *Sept:475*
- Pennsylvania
  - Pennsylvania Milk Network
    - July-Sept 1967, *Feb:100*
    - Oct-Dec 1967, *May:259*
    - Jan-Mar 1968, *Aug:432*
    - Apr-July 1968, *Nov:652*
    - August 1968, *Dec:730*
- Personnel monitoring of radiologists during fluoroscopy, *Nov:627*
- Pinellas Peninsula Plant
  - Jan-June 1967, *Feb:135*
- Plutonium—*see also* atmospheric contaminants
  - Plutonium in airborne particulates and precipitation, July-December 1967, *Dec:761*
- Polonium-210 in tobacco, *Mar:145*
- Portsmouth Area Gaseous Diffusion Plant
  - Jan-June 1967, *Jan:59*
  - July-Dec 1967, *July:384*
- Precipitation—*see* atmospheric contaminants; fallout; Radiation Alert Network, Radiation Surveillance Network; strontium-90
- Project Dribble
  - Offsite environmental surveillance findings associated with underground nuclear testing; Project Dribble, *Feb:73*

R

- Radiation Alert Network—*see also* Radiation Surveillance Network
  - Nov 1967, *Mar:173*
  - Dec 1967, *Apr:226*
  - Jan 1968, *May:273*
  - Feb 1968, *June:313*
  - Mar 1968, *July:372*
  - Apr 1968, *Aug:450*
  - May 1968, *Sept:505*
  - June 1968, *Oct:571*
  - July 1968, *Nov:674*
  - Aug 1968, *Dec:757*
- Radiation Surveillance Network
  - Sept 1967, *Jan:46*
  - Oct 1967, *Feb:113*
- Radioactivity in airborne particulates and precipitation—*see also* Canada; fallout; Mexico; National Air Sampling; Pan American Health Organization; Radiation Alert Network; Radiation Surveillance Network
- Radiology
  - Personnel monitoring of radiologists during fluoroscopy, *Nov:627*
- Radionuclides in Institutional diet somples, *see* Diet
- Radium
  - Radium survey in Alabama, *Jan:16*
- Radon
  - Suggested biological monitoring for radon daughter exposure, *Feb:81*
- Raw milk—*see also* milk
  - A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966, *Sept:475*
- Reindeer—*see* caribou
- Reported nuclear detonations
  - Dec 1967, *Jan:62*
  - Jan 1968, *Feb:142*
  - Feb 1968, *Mar:194*
  - Mar 1968, *Apr:240*
  - Apr 1968, *May:287*
  - May 1968, *June:335*
  - June 1968, *July:385*
  - July 1968, *Aug:465*
  - Aug 1968, *Sept:524*
  - Sept 1968, *Oct:617*
  - Oct 1968, *Nov:704*
  - Nov 1968, *Dec:771*
- Rocky Flats
  - Jan-June 1967, *Jan:60*
  - July-Dec 1967, *May:285*
  - Jan-June 1968, *Nov:70*

S

- Savannah River Plant
  - Jan-June 1967, *Feb:136*
  - July-Dec 1967, *June:329*
- Shellfish
  - Radionuclides in Washington shellfish, July 1964 through December 1967, *Nov:697*
- State milk surveillance networks—*see* California; Colorado; Connecticut; Florida; Indiana; Iowa; Michigan; Minnesota; New York; Oklahoma; Oregon; Pennsylvania; Tennessee; Texas; Washington
- Strontium-90—*see also* Alaska, atmospheric contaminants; bone; diet; food; environmental levels at AEC installations; milk; water
  - Strontium-90 in human bone
    - Apr-June 1967, *Sept:514*
    - July-Sept 1967, *Oct:602*
  - Strontium-90 in human vertebrae, 1967, *Oct:605*
- Suggested biological monitoring for radon daughter exposure, *Feb:81*
- Summary of gonadal and genetically significant dose from x-rays in the United States, 1964, *Oct:539*
- Summary of iron-55 contamination in the environment and levels in humans, *Apr:195*
- Surface air—*see also* atmospheric contaminants; fallout; Radiation Alert Network
  - Gamma-emitting fallout in surface air at Fort Collins, Colorado, 1962-1967, *Aug:407*
- Surface water—*see also* Atomic Energy Commission installations; Cailfornia; Colorado; Florida; Kansas; Minnesota; New York; tritium; Washington; water
  - Gross radioactivity of the solids in selected surface waters of the United States, 1961-1965, *Jan:1*
  - Tritium in surface waters of the United States, 1966, *July:337*
- Survey of therapeutic x-ray installations in Alabama, *Jan:13*

T

- Television—*see* color television receivers
- Tennessee
  - Tennessee Milk Network
    - July-Sept 1967, *Jan:30*
    - Oct-Dec 1967, *Apr:213*
    - Jan-Mar 1968, *July:356*
    - Apr-June 1968, *Oct:554*
    - July 1968, *Nov:653*
    - August 1968, *Dec:730*
- Texas
  - Texas Milk Network
    - July-Sept 1967, *Jan:31*
    - Oct-Dec 1967, *Apr:215*
    - Jan-Mar 1968, *July:357*
    - Apr-June 1968, *Oct:555*
    - July 1968, *Nov:654*
    - August 1968, *Dec:730*
- Thermoluminescent radiation dosimetry applied to dental x-ray exposures, *Aug:397*
- Thyroid—*see* bovine thyroid
- Tri-City diet study—*see* diet
- Tritiated moisture in the atmosphere surrounding a nuclear fuel reprocessing plant, *July:341*
- Tritium
  - Tritium in surface waters of the United States, 1966, *July:337*
  - Tritium in surface water network, 1967, *Oct:564*
    - Jan-June 1968, *Nov:665*

U, V

- Underground testing—*see also* reported nuclear detonations
  - Offsite environmental surveillance findings associated with underground nuclear testing; Project Dribble, *Feb:73*
- Uranium
  - Alpha radiation exposure levels in underground uranium and other mines, *Dec:719*
  - Suggested biological monitoring for radon daughter exposure, *Feb:81*

W

- Washington
  - A procedure for evaluating environmental radiation dose to children in the vicinity of the Hanford Project in Washington, April 1965-January 1967, *Aug:402*
  - Radioactivity in Washington surface water, July 1966-June 1967, *Aug:438*
  - Radionuclides in Washington shellfish, July 1964 through December 1967, *Nov:697*
  - Washington Milk Network
    - July-Sept 1967, *Mar:164*
    - Oct-Dec 1967, *June:299*
    - Jan-Mar 1968, *Sept:498*
    - Apr-July 1968, *Nov:655*
    - August 1968, *Dec:730*
- A summary of the Washington, D.C. metropolitan area survey of color television receivers, *Oct:531*
- Water—*see also* Atomic Energy Commission installations; California; Colorado; Florida; Kansas; Minnesota; New York; tritium; Washington
  - Drinking water analysis program, 1961-1966, *Aug:442*
  - Gross radioactivity of the solids in selected surface waters of the United States, 1961-1965, *Jan:1*
  - Gross radioactivity in surface waters of the United States
    - July 1967, *Jan:38*
    - August 1967, *Feb:106*
    - Sept 1967, *Mar:169*
    - Oct 1967, *Apr:222*
    - Nov 1967, *May:266*
    - Dec 1967, *June:306*
    - Jan 1968, *July:366*
    - Feb 1968, *Aug:436*
    - Mar 1968, *Sept:502*
    - Apr 1968, *Oct:562*
    - May 1968, *Nov:660*
    - June 1968, *Dec:750*
  - Gross radioactivity, May 1968, and strontium-90, July 1966-September 1967, in surface waters of the United States, *Nov:660*
  - Radiostrontium in tap water
    - Jan-June 1967, *Apr:224*
    - July-Dec 1967, *June:311*
- Whole body cesium-137 and its relation to body composition and diet, *Nov:619*

X, Y, Z

- X ray
  - A pilot survey of x-radiation emissions from color television receivers in Pinellas County, Florida *Oct:525*
  - Summary of gonadal and genetically significant dose from x rays in the United States, 1964, *Oct:539*
  - Survey of therapeutic x-ray installations in Alabama, *Jan:13*
  - Thermoluminescent radiation dosimetry applied to dent x-ray exposures, *Aug:397*

Author Index

RADIOLOGICAL HEALTH DATA AND REPORTS Volume 9–1968

Aase, J. M. Aug:387
Archer, V. E. Feb:81

Beasley, T. M. Aug.387
Bevis, H. A. Aug:391
Black, S. C. Mar:145
Bretthauer, E. W. Mar:145
Brill, W. A. Feb:63; Apr:195
Briscoe, O. G. Dec:705
Brown, M. L. Oct:539
Burdine, J. A. Nov:627
Bushong, S. C. Nov.627

Caldwell, R. D. Dec:725
Carter, M. W. Feb:73
Cohen, N. L. Nov:619
Cornish, A. C. Sept:467
Cowan, E. Jan:13; Jan.16
Crosby, R. F. Dec:725

Daly, J. C. July:341
Dickinson, M. B. Aug:397
Dunavant, B. G. Aug:391

Gabay, J. J. July:341
Gallegos, A. Aug:412

Harle, T. S. Nov:627
Harvey, Jr., H. D. Feb:73
Honstead, J. F. Aug:402
Howley, J. R. Aug:397
Hutson, E. M. Nov:619

Isaacs, E. Nov:619

Jenkins, C. E. Aug:387
Julian, E. C. Jan:1

Kunkel, N. D. Nov:619

Langford, J. C. Aug:387
Lockard, M. P. Dec:725

Manchester, A. V. July:341
Mikkelsen, R. L. Dec:705
Moghissi, A. A. July:337

Palmer H. E. Aug:387
Pogonowska, M. Nov:627
Porter, C. R. July:337

Rechen, H. J. L. Dec:705
Robbins, C. Aug:397
Robinson, P. B. Sept:475
Roessler, C. E. Aug:391
Roessler, G. S. Aug:391

Sargent, T. W. Nov:619
Sax, N. I. July:341
Segal, P. Oct:539
Snavely, D. R. Feb:63
Steiner, Jr., J. F. Dec:705
Steinkamp, R. C. Nov:619

Ward, G. M. Aug:407; Aug:412
Willis, W. T. Jan:13; Jan:16
Wilson, D. W. Aug:407

Uyesugi, G. Sept:467

233

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

CESIUM-137 CONCENTRATIONS IN ALASKANS DURING THE SPRING OF 1967. *H. J. L. Rechen, R. L. Mikkelsen, O. G. Briscoe, and J. F. Steiner, Jr. Radiological Health Data and Reports, Vol. 9, December 1968, pp. 705–717.*

During April and May 1967, ecsium-137 concentrations were measured by the National Center for Radiological Health, Public Health Service, in 1,334 residents of 13 Alaskan villages and cities where caribou and reindeer are major sources of meat. Unshielded 7.5 x 7.5 cm NaI (Tl) scintillation detectors, held in the lap, were used for subjects of both sexes, from 4 to 91 years old, weighing 16 to 100 kilograms. The maximum cesium-137 concentrations ranged from 16.58 to 20.76 nCi/kg for males and from 12.92 to 18.21 nCi/kg for females.

Cesium-137 concentrations were highest in Ambler, Selawik, Noorvik, Shungnak, and Anaktuvuk Pass, intermediate in Shishmaref, Noatak, Mekoryuk, Egegik and Teller, and lowest in three coastal cities where whaling is done (Wainwright, Point Hope and Barrow).

The Bureau of Indian Affairs school lunch program, where practiced, did not appear to reduce significantly the cesium-137 concentrations in children. Average concentrations in men who were measured both years at Anaktuvuk Pass dropped 37.5 percent from 1966 to 1967; Selawik males showed a 15.7 percent decrease, while cesium-137 concentrations in adult male residents of Egegik increased 2 percent.

The "radiation dose index," defined in the report for the highest individual value measured in 1967 was 0.17 rad/year, in an 82 kg man whose cesium-137 concentration was 21 nCi/kg. The guidance published by the Federal Radiation Council suggests that no protective action except for continued surveillance appears to be necessary at this time.

KEYWORDS: Alaska, caribou, cesium-137, radiation dose index, reindeer.

234

☆ U. S. GOVERNMENT PRINTING OFFICE : 1969 342-803/5